QUAIN'S ANATOMY.

Seventh Edition.

EDITED BY

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PART III.

CONTAINING

THE DESCRIPTIVE ANATOMY OF THE ORGANS OF SENSE AND VISCERA, WITH SURGICAL ANATOMY, DISSECTIONS, AND THE CONCLUSION OF THE GENERAL ANATOMY.

ILLUSTRATED BY 300 ENGRAVINGS ON WOOD.

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TO THE BINDER.

In Binding,

Vol. I. is to contain—

General Anatomy, pp. i. to ccxxvii.

Descriptive Anatomy, pp. 1 to 500, with the addition of the four pages 501* to 504*, contained in this Part.

Vol. II. is to contain—

Descriptive Anatomy, &c., and Index, pp. 501 to 1147.

A cancel for Vol. I. pp. 225, 226, is given in this Part.

the common extensor through a compartment of the annular ligament, comes in contact with the tendon from that muscle destined for the index finger, and unites with it to form the expansion already described.

Fig. 185.

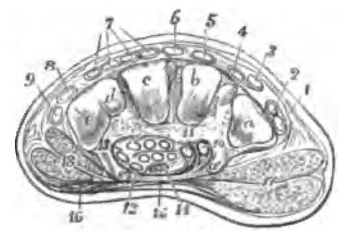

Fig. 185.—TRANSVERSE SECTION OF THE RIGHT HAND BETWEEN THE CARPUS AND METACARPUS, SHOWING THE ANTERIOR ANNULAR LIGAMENT OF THE CARPUS, AND THE PLACES OF THE VARIOUS EXTENSOR AND FLEXOR TENDONS, SEEN FROM THE DISTAL SIDE. ½

This figure is also designed to show the transverse arch formed by the second row of carpal bones. *a*, metacarpal articular surface of the trapezium for the metacarpal bone of the thumb; *a'*, palmar ridge of the trapezium; *b*, articular surface of the trapezoid bone for the second metacarpal bone; *c*, the surface of the os magnum for the middle metacarpal; *d*, the surface of the unciform for the fourth, and *e*, that for the fifth metacarpa bone; *e'*, unciform process; between *a'* and *e'*, the cut edge of the annular ligament is represented, the ends attached to the projecting parts of these bones, and sending another process towards the trapezium at 11, by which the tendon of the flexor carpi radialis is enclosed in the groove of the trapezium; 1, tendon of extensor ossis metacarpi pollicis; 2, extensor primi internodii; 3, extensor secundi internodii; 4, extensor indicis; 5 and 6, long and short radial extensors of the carpus; 7, the four divisions of the tendon of the common extensor of the fingers, the middle two belong to the third and fourth fingers; 8, extensor minimi digiti; 9, extensor carpi ulnaris; 10, flexor carpi radialis; 11, flexor longus pollicis; 12, the first on the ulnar side of the tendons of the flexor superficialis digitorum; 13, the same of the flexor profundus; 14, the median nerve; 15, points to the middle of the cut margin of the palmar aponeurosis stretched across the annular ligament; 16, the fibres of the palmaris brevis muscle; 17, cut surface of the muscles of the ball of the thumb; 18, muscles of the little finger.

MUSCLES OF THE HAND.

Besides the tendons of the long muscles and the lumbricales already described, there are placed in the hand one superficial muscle called palmaris brevis, the short muscles of the thumb and little finger, and the interossei muscles.

The *palmaris brevis* is a thin flat subcutaneous muscle, which arises from the inner margin of the palmar fascia and annular ligament; its fibres proceed transversely inwards, and are inserted into the skin along the inner border of the palm.

The palmaris brevis crosses the muscles of the little finger and covers the ulnar artery and nerve. It is subject to considerable variation in its breadth and thickness, consisting sometimes of only a few scattered fibres.

MUSCLES OF THE THUMB.—The fleshy mass which forms the *thenar prominence*, or ball of the thumb, consists of four muscles.

The *abductor pollicis* (abductor brevis pollicis,—Alb.), superficial and flat, arises from the annular ligament and from the ridge of the os trapezium, and, proceeding outwards and forwards, is inserted by a tendon into the radial border of the first phalanx of the thumb at its base.

The *opponens pollicis*, placed behind the abductor, arises from the annular ligament and from the os trapezium and its ridge, and is inserted intothe whole length of the metacarpal bone of the thumb at the radial border.

The *flexor brevis pollicis* arises by two heads, a superficial and a deep. The superficial head is attached to the outer two-thirds of the annular ligament and to the os magnum: the deep head is attached to the os trapezoides and os magnum, to the sheath of the flexor carpi radialis and to the bases of the second and third metacarpal bones. From the superficial and deep heads of origin two strong masses of fibres which, becoming tendinous, are attached to the outer and inner sesamoid bones respectively, and are inserted into the sides of the base of the first phalanx of the thumb; the outer head is also joined by a considerable fasciculus from the deeper origin; the inner head is inserted conjointly with the adductor pollicis. The two tendons of insertion, with the sesamoid bones, play over the grooved surfaces of the first metacarpal bone. The tendon of the long flexor lies between the heads of origin, and grooves the surface of the muscle as it passes between the tendons of insertion.

Fig. 186.

Fig. 186.—Muscles and Tendons of the Palmar Aspect of the Hand. ½

A portion of the tendons of the superficial flexor has been cut away to show those of the deep flexor and the lumbricales. 1, tendon of the flexor carpi radialis, cut short near the place where it enters the canal in the outer attachment of the annular ligament of the carpus; 2, tendon of the flexor carpi ulnaris, inserted into the pisiform bone; 3, anterior annular ligament of the carpus; 4, abductor pollicis; 5, opponens pollicis; 6, 6, flexor brevis; 7, adductor pollicis; 8, abductor minimi digiti; 9, flexor brevis minimi digiti; 10, lumbricales, passing to their insertion on the radial side of the four fingers.

Fig. 187.

Fig. 187.—Deep Muscles of the Palm of the Hand. ½

The abductor pollicis and abductor minimi digiti, together with the anterior annular ligament and the long flexor tendons in the palm, have been removed; in the forefinger the tendons of both the superficial and deep flexors remain; in the other fingers the tendons of the superficial flexor have been removed. 1, pronator quadratus muscle; 2, opponens pollicis; 3, flexor brevis pollicis; 4, adductor pollicis; 5, opponens minimi digiti; 6, unciform bone; 7, 8, interosseous muscles.

The *adductor pollicis* arises from the anterior two-thirds of the palmar surface of the metacarpal bone of the middle finger, and is inserted into the

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ADVERTISEMENT.

THE successive Editions of Dr. Jones Quain's "Elements of Anatomy" were, up to the fourth inclusive, published under the superintendence of the Author. The duty of editing the fifth edition was undertaken by Mr. Richard Quain, then Professor of Anatomy in University College, and Dr. Sharpey; the several parts being apportioned between them, as follows, viz.:—The General Anatomy to Dr. Sharpey, with the Descriptive Anatomy of the Brain, the Heart, and of the Organs of Respiration, Voice, Digestion, Urine, and Generation; and to Mr. Quain the remaining portion of the Descriptive Anatomy, comprehending the Bones, Muscles, Articulations, Fasciæ, Vessels, Nerves, and the Organs of the Senses, together with the Surgical Anatomy of the different regions. On that occasion extensive changes were made throughout the work, and a great part was entirely re-written.

The increasing claims of professional duty having prevented Mr. Quain from continuing his services in preparing the Sixth Edition, his place was taken by Mr. Ellis, his successor in the Chair of Anatomy at University College, who was accordingly associated with Dr. Sharpey, and edited that portion of the work which had previously fallen to the share of his predecessor.

In the present edition the General Anatomy, entirely re-written by Dr. Sharpey for the fifth edition, has been again revised by him, and has undergone extensive changes, adapting it to the present state of the science. The whole of the Descriptive Anatomy has been edited by Dr. Thomson and Dr. Cleland. The text of this part has been thoroughly revised, and in great measure recast by Dr. Cleland, with the assistance and supervision of Dr. Thomson. New figures have in most cases been substituted for those of former editions, drawn on a larger scale, or deemed otherwise more

illustrative of the objects, and many additional figures have been introduced. The duty of selecting these figures and superintending their execution has been performed by Dr. Thomson. All those of the bones, and most of those of the joints have been drawn from the natural objects. Many of the figures of the muscles were also drawn from nature, and most of the others, though founded on approved published prints, have been modified and finished from actual dissections. When figures are not original, the sources whence they have been taken are faithfully indicated. Of those borrowed from the works of Kölliker, Sappey, and Frey, a certain number are impressions from electro-type copies, obtained through the courtesy of the authors and publishers of these works. The new cuts have been executed chiefly by Messrs. Robert Tennant and Stephen Miller, of Glasgow; the former as draughtsman, the latter as engraver. Several of those new to the General Anatomy are by Mr. W. H. Wesley, of London.

The Section on Surgical Anatomy has been reprinted as originally written by Professor R. Quain, with only a few verbal alterations.

Instead of the paragraphs headed "dissection," distributed through the work in former editions, it has been thought preferable to supply a systematic but concise set of directions for dissection at the end of the book. Whilst it is hoped that this chapter will add to the utility of the work, it is by no means intended that it should supersede the use of special Manuals of Practical Anatomy.

CONTENTS OF THE FIRST VOLUME.

ELEMENTS OF ANATOMY.

	PAGE
INTRODUCTION	i

GENERAL ANATOMY.

	PAGE
GENERAL CONSIDERATIONS ON THE TEXTURES	iii
Physical Properties	iv
Chemical Composition	v
Vital Properties	vii
DEVELOPMENT OF THE TEXTURES	ix
Structure of Cells	xiii
Production of Cells	xv
Motion of the Protoplasm in Cells	xix
Relation of Cells to the formation of textures	xxi
Intercellular substance	xxiii
NUTRITION and Regeneration of the Textures	xxiv
THE BLOOD	xxvii
Physical and Organic Constitution	xxvii
Chemical Composition	xxxiii
Red Corpuscles	xxxiii
Liquor Sanguinis	xxxvii
Origin of Fibrin	xxxviii
Serum	xxxix
Mean Composition of the Blood	xli
Different kinds of Blood	xlii
Coagulation of the Blood	xliv
THE LYMPH AND CHYLE	xlvii
Lymph	xlviii
Chyle	xlviii
Formation of the Corpuscles of the Lymph and Chyle	l
Formation of the Blood-Corpuscles	l
EPIDERMIC, EPITHELIAL, OR CUTICULAR TISSUE	lii
General nature	lii
Scaly Epithelium	liii
Columnar Epithelium	lvi
Spheroidal Epithelium	lviii
Ciliated Epithelium	lviii
Motion of Cilia	lxi
PIGMENT	lxiii
ADIPOSE TISSUE	lxv
CONNECTIVE TISSUE	lxix
Areolar Tissue	lxix
Fibrous Tissue	lxxiv
Yellow or Elastic Tissue	lxxvi
Special Varieties of Connective Tissue	lxxviii
CARTILAGE	lxxx
Hyaline Cartilage	lxxxi
Elastic or Yellow Cartilage	lxxxv
Fibro-Cartilage	lxxxvi
BONE OR OSSEOUS TISSUE	lxxxvii
External Configuration	lxxxvii
Physical Properties	lxxxviii
Chemical Composition	lxxxix
Structure	xc
Periosteum	c
Marrow	c
Blood-vessels, &c.	ci
Formation and Growth of Bone	cii
Ossification in Membrane	ciii
Ossification in Cartilage	cvi
MUSCULAR TISSUE	cxv
General Structure of Voluntary Muscles	cxv
Structure of the Fibres	cxviii
Connection with Tendons	cxxi
Blood-vessels and Lymphatics	cxxiii
Nerves	cxxiv
Involuntary Muscles	cxxiv
Development of Muscle	cxxvi
Growth of Muscles	cxxvii
Chemical Composition of Muscle	cxxviii
Physical and Vital Properties of Muscle	cxxix
NERVOUS SYSTEM	cxxxi
Chemical Composition	cxxxiii
Structural Elements	cxxxiv
Ganglia	cxli
Cerebro-Spinal Nerves	cxliv
The Sympathetic or Ganglionic Nerve	clviii
Vital Properties of the Nervous System	clxii
Development of Nerves	clxiii

	PAGE
BLOOD-VESSELS	clxv
Arteries	clxvii
Veins	clxxii
Capillary Vessels	clxxv
Development of Blood-Vessels	clxxx
ABSORBENT OR LYMPHATIC SYSTEM	clxxxii
Distribution and Origin	clxxxii
Structure	clxxxiv
Absorbent Glands	clxxxvi
SEROUS MEMBRANES	cxci
SYNOVIAL MEMBRANES	cxciii
MUCOUS MEMBRANES	cxcv
Structure	cxcvii
Glands of Mucous Membrane	cc
Nerves	cci
Secretion	cci
SKIN	cci
The Epidermis or Cuticle	cci
The True Skin, its Structure	cciii
Papillæ	cciv
Blood-vessels and Lymphatics	ccv
Nerves	ccvi
Nails	ccvi
Hairs	ccviii
Glands of the Skin	ccxv
SECRETING GLANDS	ccxviii
DUCTLESS OR VASCULAR GLANDS	ccxxvi

SPECIAL ANATOMY.

DIVISION I.—SYSTEMATIC OR DESCRIPTIVE ANATOMY.

	PAGE
SECTION I.—OSTEOLOGY	2
The Skeleton	2
I. THE VERTEBRAL COLUMN	3
Moveable Vertebræ	4
General Characters	4
Characters Peculiar to Groups of Vertebræ	5
Dorsal Vertebræ	5
Lumbar Vertebræ	6
Cervical Vertebræ	7
The First and Second Cervical Vertebræ	8
Fixed or United Vertebræ	10
Sacrum	10
Coccyx	12
The Vertebral Column as a whole	13
Development of the Vertebræ	15
Periods of Ossification	20
Theoretical Comparison of the Vertebræ	21
II. THE THORAX	23
The Sternum or Breast-Bone	23
The Ribs	24
The Thorax as a whole	27
Development of the Ribs and Sternum	27
Periods of Ossification of the Ribs and Sternum	29
III. THE BONES OF THE SKULL	29
Occipital Bone	29
Frontal Bone	33
Temporal Bone	35
Sphenoid Bone	38
Ethmoid Bone	42
Superior Maxillary Bone	44
Palate Bone	46
Vomer	48
Malar Bone	49
Nasal Bone	49
Lachrymal Bone	50
Inferior Turbinated Bone	50
Inferior Maxillary Bone	51
Hyoid Bone	52
THE SKULL AS A WHOLE	53
The Sutures	53
General Conformation of the Skull	55
Exterior	55
Interior	60
Development of the Skull	64
Periods of Ossification of the Bones of the Skull	70
The Vertebral Theory of the Skull	71
The Various Forms of the Skull	72
IV. BONES OF THE UPPER LIMB	74
Scapula	74
Clavicle	77
Humerus	78
Radius	80
Ulna	81
Carpus	83
Scaphoid Bone	84
Semilunar Bone	84
Cuneiform Bone	84
Pisiform Bone	85
Trapezium	85
Trapezoid Bone	85
Os Magnum	85
Unciform Bone	86
Metacarpus	86
Digital Phalanges	87
Development of the Upper Limb	88
Periods of Ossification of the Bones of the Upper Limb	90

	PAGE
V. THE PELVIS AND LOWER LIMB	93
Innominate Bone	93
The Pelvis	97
Femur	100
Patella	103
Tibia	103
Fibula	105
Tarsus	106
Calcaneum	107
Astragalus	107
Cuboid Bone	108
Scaphoid Bone	108
Cuneiform Bones	109
Metatarsus	109
Digital Phalanges	110
The Bones of the Foot as a whole	110
Development of the Lower Limb	110
Periods of Ossification of the Bones of the Lower Limb	112
Comparison of the Upper with the Lower Limb	115
Relation of the Limbs to the Segments of the Trunk	117
The Skeleton adapted to the Erect Posture	117
SECTION II.—ARTHROLOGY	118
Modes of Articulation	118
Motions of the Bones in the joints	120
ARTICULATIONS OF THE TRUNK AND HEAD	121
Articulations of the Vertebral Column	121
Articulations of the Atlas, Axis, and Occipital Bone	125
Articulations of the Ribs	128
Temporo-Maxillary Articulation	132
ARTICULATIONS OF THE UPPER LIMB	134
The Scapulo-Clavicular Arch	134
The Shoulder-Joint	136
Articulations of the Fore-arm and Elbow	138
The Wrist-Joint and Articulation of the Hand	142
Connection of the Metacarpal Bones with the Carpus, and with each other	144
Articulations of the Metacarpal Bones with the Phalanges, and of the Phalanges with each other	145
ARTICULATIONS OF THE PELVIS	147
ARTICULATIONS OF THE LOWER LIMB	151
The Hip-Joint	151
The Knee-Joint	153
Articulations of the Leg and Ankle	158
Articulations of the Foot	160
SECTION III.—MYOLOGY	167
MUSCLES OF THE HEAD AND NECK	169
Superficial Muscles	169
Epicranial Muscles	169
Muscles of the Eyelids	171
Muscles of the Nose	173
Muscles of the Lips and Mouth	175
Muscles of the Orbit	179
Action of	179, 501*
Muscles of the Jaw	181
Submaxillary Muscles	183
A.—Muscles connecting the Hyoid Bone with the Skull	183
B.—Muscles of the Tongue	185
Muscles of the Pharynx and Soft Palate	187
Muscles depressing the Hyoid Bone	191
Flexor Muscles of the Neck	193
Fasciæ of the Head and Neck	196
MUSCLES OF THE UPPER LIMB	198
Muscles attaching the Upper Limb to the Trunk posteriorly	200
Muscles attaching the Upper Limb to the Trunk anteriorly	203
Muscles of the Shoulder	208
Muscles of the Arm	212
Muscles of the Fore-Arm	215
a. Anterior and Inner Regions (Flexors and Pronators	215
b. Posterior and Outer Regions (Extensors and Supinators)	220
Muscles of the Hand	225
Muscles of the Thumb	225
Muscles of the Little Finger	227
Action of the Muscles of the Fore-Arm and Hand	228
Fasciæ of the Upper Limb	229
MUSCLES OF THE TRUNK	232
Dorsal Muscles of the Trunk (Muscles of the Back)	232
Dorsal and Lumbar Fasciæ	240
Muscles of the Thorax	240
Diaphragm	243
Movements of Respiration	246
MUSCLES OF THE ABDOMEN	248
Fasciæ of the Abdomen	257
Fasciæ of the Perinæum	259
Fasciæ of the Pelvis	260
Muscles of the Perinæum	261
A.—In the Male	261
B.—In the Female	265
MUSCLES OF THE LOWER LIMB	266
Muscles of the Hip and Thigh	266
Gluteal Region	266
Posterior Femoral Region (Hamstring Muscles)	270

	PAGE
Iliac Region	271
Anterior Femoral Region	273
Internal Femoral Region (Adductor Muscles)	276
Action of the Muscles of the Hip and Thigh	279
Muscles of the Leg and Foot	279
Anterior Region of the Leg	279
External Region	282
Posterior Region	282
Short Plantar Muscles	289
Muscles of the Great Toe	289
Muscles of the Little Toe	290
Action of the Muscles of the Leg and Foot	291
Fasciæ of the Lower Limb	292
SECTION IV.—ANGEIOLOGY	297
THE HEART	297
Relation to Surrounding Parts	297
The Mediastinum	297
Pericardium	300
External Form of the Heart	302
Interior of the Heart	304
General Description	304
Special Description	308
Position of the Parts of the Heart with Relation to the Wall of the Thorax	313
Fibrous and Muscular Structure of the Heart	316
Vessels and Nerves	321
Weight and Dimensions	321
Development of the Heart and Great Blood-Vessels	323
Peculiarities of the Fœtal Heart and Great Vessels.—Fœtal Circulation	327
PULMONARY VESSELS	331
Pulmonary Artery and Veins	331
SYSTEMIC VESSELS	332
ARTERIES	332
AORTA	332
Arch of the Aorta	332
Peculiarities of the Arch of the Aorta	336
BRANCHES OF THE ARCH OF THE AORTA	338
Coronary Arteries	338
Innominate Artery	340
Common Carotid Arteries	341
External Carotid Artery	345
Branches of the External Carotid Artery	346
Superior Thyroid Artery	346
Lingual Artery	348
Facial Artery	349
Occipital Artery	351
Posterior Auricular Artery	353
Temporal Artery	353
Internal Maxillary Artery	354
Ascending Pharyngeal Artery	357
Internal Carotid Artery	359
Branches of the Internal Carotid Artery	360
Ophthalmic Artery	360
Anterior and Middle Cerebral Arteries	363
Circle of Willis	363
Subclavian Arteries	364
Branches	367
Vertebral Artery	367
Thyroid Axis	371
Inferior Thyroid	371
Suprascapular	371
Transverse Cervical	373
Internal Mammary Artery	374
Superior Intercostal and Deep Cervical Arteries	376
Axillary Artery	377
Branches	377
External Thoracic Branches	379
Subscapular Artery	379
Circumflex Arteries	380
Brachial Artery	381
Branches	383
Ulnar Artery	388
Branches	389
Recurrent Branches	389
Interosseous Artery	390
Muscular Branches	391
Carpal Branches	391
Superficial Palmar Arch	393
Radial Artery	394
Branches	397
Deep Palmar Arch	400
Various Conditions of the Arteries of the Hand	400
THORACIC AORTA	401
Branches	402
Bronchial Arteries	402
Œsophageal Arteries	402
Intercostal Arteries	402
ABDOMINAL AORTA	404
A.—Visceral Branches	406
Cœliac Artery or Axis	406
Coronary Artery of the Stomach	407
Hepatic Artery	408
Splenic Artery	408
Superior Mesenteric Artery	410
Branches	410
Inferior Mesenteric Artery	412
Branches	412
Anastomoses on the Intestinal Tube	412
Capsular or Suprarenal Arteries	413
Renal or Emulgent Arteries	414
Peculiarities	414
Spermatic and Ovarian Arteries	414
B.—Parietal Branches of the Abdominal Aorta	416
Inferior Phrenic Arteries	416
Branches	416
Lumbar Arteries	417

PAGE
Branches 417
Minute Anastomoses of the Visceral and Parietal Branches of the Abdominal Aorta . . 417
Middle Sacral Artery . . 418
Common Iliac Arteries . 418
Internal Iliac Artery . . 420
Hypogastric Artery . 420
Branches of the Internal Iliac Artery 421
Vesical Arteries . . 421
Uterine and Vaginal Arteries 422
Obturator Artery . . 423
Branches . . . 424
Pudic Artery . . . 425
Branches 426
Sciatic Artery . . . 429
Gluteal Artery . . 429
Ilio-Lumbar Artery . . 429
Lateral Sacral Arteries . 430
External Iliac Artery . . 431
Epigastric Artery . . 432
Circumflex Iliac Artery . 433
Femoral Artery . . . 434
Superficial Inguinal Branches . . . 437
Deep Femoral Artery . 437
Muscular Branches . . 439
Anastomotic Artery . 440
Popliteal Artery . . . 441
Branches 442
Posterior Tibial Artery . 444
Small Branches . . . 444
Peroneal Artery . . 444
Plantar Arteries . . . 446
Branches 447
Anterior Tibial Artery . . 448
Branches 449
Dorsal Artery of the Foot . 450
VEINS 452
UPPER VENA CAVA . . 453
Innominate or Brachio-Cephalic Veins . . 453
Lateral Tributaries . 453
Veins of the Face, Neck and Head . . . 455
Facial Vein . . . 455
Temporal Vein . . . 457
Internal Maxillary Vein 457
Facial Communicating Vein . . . 457

PAGE
External Jugular Vein 459
Internal Jugular Vein . 459
Venous Circulation within the Cranium . . 460
Cerebral Veins . . 460
Cranial Sinuses . . 461
Ophthalmic Vein . . 464
Veins of the Diploë . 465
Superficial Veins of the Upper Limb . . 466
Deep Veins of the Upper Limb . . . 467
Axillary Vein . . . 468
Subclavian Vein . . 469
Azygos Veins . . . 469
Veins of the Spine . . 471
LOWER VENA CAVA . . . 473
Veins of the Lower Limb and Pelvis 475
Superficial Veins of the Lower Limb . . 475
Deep Veins of the Lower Limb 476
Femoral Vein . . . 476
External Iliac Vein . . 477
Internal Iliac Vein . . 477
Common Iliac Vein . . 479
PORTAL SYSTEM OF VEINS . 479
Portal Vein or Vena Portæ . 479
Coronary Vein of Stomach 480
Splenic Vein . . . 480
Mesenteric Veins . . 481
VEINS OF THE HEART . . 482
Development of the Great Veins 483
ABSORBENTS 486
Thoracic Duct . . . 487
Right Lymphatic Duct . . 488
Lymphatics of the Lower Limb, and Surface of the Lower Half of the Trunk 488
Absorbents of the Abdomen and Pelvis . . . 490
Lymphatics of the Thorax . 495
Lymphatics of the Upper Limb, and of the Breast and Back . . . 497
Lymphatics of the Head and Neck 499

NOTE.—On Action of Muscles of the Eye . . . 501*

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CONTENTS OF THE SECOND VOLUME.

DIVISION I.—SYSTEMATIC AND DESCRIPTIVE ANATOMY (CONTINUED).

	PAGE
SECTION V.—NEUROLOGY	501
I. THE CEREBRO-SPINAL AXIS	501
A. THE SPINAL CORD	502
Its description	502
Internal structure	507
Central Canal	508
Minute structure of the Cord	509
Origin of the Spinal Nerves	511
B. THE ENCEPHALON	513
The Medulla Oblongata	514
Course of fibres through the Medulla	518
Grey matter of the Medulla	519
The Pons Varolii and Cerebellum	521
Pons Varolii	521
The Cerebellum	522
Its internal structure	526
The Cerebrum	529
Exterior of the Cerebrum	529
Cerebral Convolutions	531
Base of the Cerebrum	536
Internal Parts of the Cerebrum	540
Lateral Ventricles	543
Third Ventricle	550
Internal Structure of the Cerebrum	554
White matter	555
Grey matter	559
Membranes of the Brain and Spinal Cord	562
Dura Mater	562
Pia Mater	564
Arachnoid Membrane	565
Blood-vessels of the Brain and Spinal Cord	567
Size and Weight of the Encephalon	568
Weight of the several parts of the Encephalon	571
Weight of the Spinal Cord	572
Specific Gravity of the Encephalon	572
Development of the Cerebro-Spinal Axis	573
of the Spinal Cord	574
of the Encephalon	575
of the membranes of the Encephalon	581
II. THE CEREBRO-SPINAL NERVES	582
A. CRANIAL NERVES	582
Connections of the Cranial Nerves with the Encephalon	583
Distribution of the Cranial Nerves	587
Olfactory Nerve	592
Optic Nerve	592
Third Pair of Nerves	593
Fourth Pair of Nerves	594
Fifth Pair of Nerves	595
Ophthalmic Nerve	597
Lachrymal Branch	597
Frontal Branch	597
Nasal Branch	598
Ophthalmic Ganglion	599
Superior Maxillary Nerve	600
Orbital Branch	600
Posterior Dental Branches	601
Anterior Dental Branch	601
Infra-orbital Branches	602
Spheno-palatine Ganglion	603
Inferior Maxillary Nerve	605
Deep Temporal, Masseteric, Buccal, and Pterygoid Branches	605
Auriculo-temporal Nerve	606
Gustatory Nerve	606
Inferior Dental Nerve	608
Otic Ganglion	608
Submaxillary Ganglion	609
Sixth Pair of Nerves	610
Seventh Pair of Nerves	610
Facial Nerve	610
Connecting Branches	611
ChordaTympani and Nerve to the Stapedius	611
Posterior Auricular Branch	612

	PAGE
Digastric and Stylo-hyoid Branches	613
Temporo-facial Division	613
Cervico-facial Division	613
Auditory Nerve	615
Eighth Pair of Nerves	615
Glosso-pharyngeal Nerve	615
Connecting Branches and Tympanic Branch	616
Branches distributed in the Neck	617
Pneumo-gastric Nerve	618
Connecting Branches and Auricular Branch	621
Pharyngeal Branch	621
Superior Laryngeal Branch	621
Recurrent Laryngeal Branch	622
Cardiac Branches	623
Pulmonary Branches	623
Œsophageal Branches	623
Gastric Branches	623
Spinal Accessory Nerve	625
Ninth Pair of Nerves	626
Connecting Branches	626
Muscular and Lingual Branches	626
B. SPINAL NERVES	628
Roots of the Spinal Nerves	630
Posterior Primary Divisions of the Spinal Nerves	632
Suboccipital Nerve	632
Cervical Nerves	633
Dorsal Nerves	634
Lumbar Nerve	634
Sacral Nerves	635
Coccygeal Nerve	635
Anterior Primary Divisions of the Spinal Nerves	635
Cervical Nerves	636
Suboccipital Nerve	636
Second Cervical Nerve	636
Cervical Plexus	636
1. Superficial Ascending Branches	638
Superficial Cervical Nerve	638
Great Auricular Nerve	638
Small Occipital Nerve	638
2. Superficial Descending Branches	639
Supraclavicular Nerves	639
3. Deep Branches: Inner Series	640
Muscular Branches	640
Phrenic Nerve	640
4. Deep Branches: External Series	641
Brachial Plexus	641
Branches above the Clavicle	643
Posterior Thoracic Nerve	644
Suprascapular Nerve	644
Branches below the Clavicle	644
Anterior Thoracic Nerve	645
Subscapular Nerve	645
Circumflex Nerves	645
Internal Cutaneous Nerve	646
Small Internal Cutaneous Nerve	646
Musculo-cutaneous Nerve	648
Ulnar Nerve	648
Median Nerve	649
Musculo-spiral Nerve	652
Radial Nerve	653
Posterior Interosseous Nerve	654
Anterior Primary Divisions of the Dorsal Nerves	655
First Dorsal Nerve	655
Upper or Pectoral Intercostal Nerves	655
Lower or Abdominal Intercostal Nerves	657
Last Dorsal Nerve	658
Anterior Primary Divisions of the Lumbar Nerves	658
Lumbar Plexus	658
Ilio-hypogastric and Ilio-inguinal Nerves	660
Genito-crural Nerve	660
External Cutaneous Nerves	662
Obturator Nerve	662
Accessory Obturator Nerve	663
Anterior Crural Nerve	664
Muscular Branches	665
Middle Cutaneous Nerve	665
Internal Cutaneous Nerve	665
Internal Saphenous Nerve	666
Fifth Lumbar Nerve	667
Superior Gluteal Nerve	667
Anterior Primary Divisions of the Sacral and Coccygeal Nerves	668
The Sacral Nerves	668
Fourth Sacral Nerv	668
Fifth Sacral Nervee	668
Coccygeal Nerve	668
Sacral Plexus	669
Muscular Branches	670
Pudic Branches	670
Small Sciatic Nerve	673
Great Sciatic Nerve	675
Internal Popliteal Nerve	676
External or Short Saphenous Nerve	677
Posterior Tibial Nerve	677
Internal Plantar Nerve	677
External Plantar Nerve	679
External Popliteal or Peroneal Nerve	679
Musculo-cutaneous Nerve	680
Anterior Tibial Nerve	681

	PAGE
Synopsis of the Cutaneous Distribution of the Cerebro-spinal Nerves	682
Synopsis of the Muscular Distribution of the Cerebro-spinal Nerves	684
Muscles of the Head and Fore Part of the Neck	684
Muscles belonging exclusively to the Trunk, and Muscles ascending to the Skull	684
Muscles attaching the Upper Limb to the Trunk	685
Muscles of the Upper Limb	685
Muscles of the Lower Limb	686
III. SYMPATHETIC NERVES	686
A. GANGLIATED CORDS	688
Cervical Part	688
Upper Cervical Ganglion	688
Ascending Branch and Cranial Plexuses	688
Pharyngeal Nerves and Plexus	690
Upper Cardiac Nerve	690
Branches to Blood-vessels	692
Middle Cervical Ganglion	692
Lower Cervical Ganglion	693
Thoracic Part	693
Branches of the Ganglia	693
Great Splanchnic Nerve	695
Small Splanchnic Nerve	696
Smallest Splanchnic Nerve	696
Lumbar Part	696
Sacral Part	696
Coccygeal Gland	697
B. GREAT PLEXUSES OF THE SYMPATHETIC	698
Cardiac Plexus	698
Superficial	698
Deep	698
Solar or Epigastric Plexus	699
Aortic Plexus	702
Hypogastric Plexus	702
Pelvic Plexus	703
IV. ORGANS OF THE SENSES	705
THE EYE	705
Appendages of the Eye	705
Eyelids and Conjunctiva	705
Lachrymal Apparatus	709
Globe of the Eye	710
External Coat of the Eyeball	711
Sclerotic Coat	711
Cornea	714
Middle Tunic of the Eyeball	716
Choroid Coat	716
Iris	718
Ciliary Muscle, Ligamentum Pectinatum, and Circular Sinus	721
Vessels and Nerves of the Middle Tunic of the Eye	721
Retina or Nervous Tunic	725
Structure of the Retina	726
Vitreous Body	731
The Lens and its Capsule	733
Lens	733
Suspensory Ligament of the Lens, and Canal of Petit	736
Aqueous Humour and its Chamber	736
Development of the Eye	736
THE EAR	740
External Ear	740
Pinna	740
External Auditory Canal	743
Middle Ear or Tympanum	744
Small Bones of the Ear	748
Ligaments and Muscles of Tympanum	749
Lining Membrane of Tympanum	751
Vessels and Nerves of Tympanum	752
Internal Ear or Labyrinth	753
Osseous Labyrinth	753
Membranous Labyrinth	757
Vestibule	757
Semicircular Canals	758
Cochlea	760
Blood-vessels of Labyrinth	767
Development of the Ear	768
NOSE	771
Cartilages of Nose	771
Nasal Fossæ	773
Mucous Membrane	774
Development of the Nose	778
SECTION VI.—SPLANCHNOLOGY	779
ORGANS OF DIGESTION	779
Mouth	779
Teeth	780
Structure	784
Development of Teeth	792
Tongue	805
Mucous Membrane	805
Muscular substance	809
Palate	813
Tonsils	813
Salivary Glands	815
Parotid Gland	815
Submaxillary Gland	816
Sublingual Gland	817
Pharynx	819
Œsophagus	821
Abdominal Digestive Organs	823
Abdomen	823
Parts situated in each Region of the Abdomen	826
The Peritoneum	826
Stomach	830
Structure of coats	832
Small Intestine	838
Structure of Small Intestine	841
Large Intestine	851
Cæcum	852

	PAGE
Colon	853
Rectum	856
Anus and its Muscles	859
Development of the Alimentary Canal and Peritoneal Cavity	859
Liver	862
Structure of Liver	869
The Bile	878
Development and Fœtal Peculiarities of Liver	879
Pancreas	881
Spleen	883
ORGANS OF RESPIRATION	888
Trachea and Bronchi	888
Structure of the Trachea	890
Pleuræ	892
Lungs	894
Root of Lung	897
Structure of Lungs	898
Development of Lungs and Trachea	904
Larynx or Organ of Voice	905
Cartilages of Larynx	905
Muscles of Larynx	914
Vessels and Nerves of Larynx	919
Development and Growth of Larynx	919
DUCTLESS GLANDS ON THE LARYNX AND TRACHEA	920
Thyroid Body	920
Thymus Gland	923
URINARY ORGANS	926
Kidneys	926
Suprarenal Bodies	939
Ureters	942
Urinary Bladder	944
Urethra	952
ORGANS OF GENERATION	952
MALE ORGANS	952
Prostate Gland	952
Penis	955
Corpora Cavernosa	956
Corpus Spongiosum	958
Urethra of the Male	959
Testes and Excretory Apparatus	963
Coverings of Testis and Cord	963
Vessels and Nerves of the Coverings of the Testis and Cord	967
Testes	967
Vas Deferens	971
Seminal Vesicles and Ejaculatory Ducts	973
Vessels and Nerves of Testis	975
FEMALE ORGANS	977
Vulva	977
Female Urethra	980
Vagina	980
Uterus	982
Ovaries and Fallopian Tubes	988
Development of the Urinary Organs	992
Development of the Organs of Generation	995
MAMMARY GLANDS	1002

DIVISION II.—SURGICAL ANATOMY.

SURGICAL ANATOMY OF THE ARTERIES	1005
Common Carotid Artery	1005
Subclavian Artery	1007
Brachial Artery	1010
Common Iliac Arteries	1012
Internal Iliac Artery	1014
External Iliac Artery	1014
Femoral Artery	1015
SURGICAL ANATOMY OF THE PARTS CONCERNED IN CERTAIN ABDOMINAL HERNIÆ	1018
The Parts concerned in Inguinal Hernia	1018
Inguinal Herniæ	1025
The Parts concerned in Femoral Hernia	1031
Femoral Hernia	1034
THE PERINÆUM AND ISCHIO-RECTAL REGION	1037
Lateral Operation of Lithotomy	1043

DIVISION III.—DISSECTIONS.

GENERAL MANAGEMENT OF THE DISSECTIONS	1047
SPECIAL DIRECTIONS FOR THE DISSECTION OF EACH PART	1048
Head and Neck	1048
Upper Limbs or Superior Extremities	1059
Thorax	1066
Abdomen and Pelvis	1069
Lower Limbs or Inferior Extremities	1078

Fasciculi.—The fasciculi are of a prismatic figure, and their sections have therefore an angular outline. The number of fibres of which they consist varies, so that they differ in thickness, and a large fasciculus may be divisible into two or three orders of successively smaller bundles, but of no regularly diminishing magnitude. Some muscles have large, others only small fasciculi; and the coarse or fine texture of a muscle, as recognized by the dissector, depends on this circumstance. The length of the fasciculi is not always proportioned to the length of the muscle, but depends on the arrangement of the tendons to which their extremities are attached. When the tendons are limited to the ends of a long muscle, as in the sartorius, the fasciculi, having to pass from one extremity to the other, are of great length; but a long muscle may be made up of a series of short fasciculi attached obliquely to one or both sides of a tendon, which advances some way upon the surface or into the midst of the fleshy part, as in the instance of the rectus muscle of the thigh, and the tibialis posticus. Muscles of the kind last referred to are named "penniform," from their resemblance to the plume of a feather, and other modifications of the arrangement, which can be readily conceived, are named "semi-penniform" and "compound penniform." Many short fasciculi connected thus to a long tendon, produce by their combined operation a more powerful effect than a few fasciculi running nearly the whole length of the muscle; but by the latter arrangement the extent of motion is greater, for the points of attachment are moved through a longer space.

Fibres; their figure and measurement.—In shape the fibres are cylindrical, or prismatic, and in the latter case often with some rounded surfaces and angles. Their size is tolerably uniform, although fibres occur here and there in a muscle which differ greatly in size from the prevailing standard. Mr. Bowman gave the average diameter in the male at $\frac{1}{352}$ and in the female at $\frac{1}{454}$ of an inch. According to later measurements by Kölliker in different regions of the body, the prevailing size of the fibres in the muscles of the trunk and limbs is from $\frac{1}{750}$ to $\frac{1}{400}$ of an inch, but is less in those of the head, especially in the facial muscles, in which he found the diameter to range from $\frac{1}{750}$ down to $\frac{1}{2400}$ of an inch.

Cross stripes.—When viewed by transmitted light with a sufficiently high power of the microscope, the fibres, which are then clear and pellucid in aspect, appear marked with fine parallel stripes or bands passing across them directly or somewhat obliquely with great regularity (figs. LX. and LXI. A). The stripes are commonly said to be dark, with light intervals; but it is probably more correct to speak of both light and dark stripes which alternately cross the fibre. It must, however, be remembered that the substance of the fibre is quite translucent, and, by changing the focus, the stripes which at first appeared dark become light, and the previously light ones are now dark. In what may be considered the definite or true focus, the dark and light stripes are nearly of equal breadth, and then also may be seen, very generally but not in all cases, a fine dark line passing along the middle of the light stripe and dividing it into two (fig. LXI. A). This intermediate line when closely examined appears to be a row of dark points. About eight or nine dark and as many light stripes may be counted in the length of $\frac{1}{1000}$ of an inch, which would give about $\frac{1}{17000}$ inch as the breadth of each. But whilst this may be assigned as their usual breadth, they are in different parts found to be much narrower, so that not unfrequently they are double the above number in an equal space. This closer approximation may generally be noticed in thicker and apparently contracted parts

of the fibre, but it is by no means confined to such parts. This cross-striped appearance, which is most beautiful and characteristic, is found in all the voluntary muscles; but it is not altogether confined to them, for it is seen in the fibres of the heart, which is a strictly involuntary organ: striped fibres are also found in the pharynx and upper part of the gullet, in the muscles of the internal ear, and those of the urethra, parts which are not under the direct control of the will.

Structure of the fibres.—A muscular fibre may be said to consist of a large number of extremely fine filaments or fibrils inclosed in a tubular sheath. This, the proper sheath of the fibre, is named *sarcolemma* or *myolemma*. It consists of transparent and apparently homogeneous membrane agreeing in chemical characters with elastic tissue, and, being comparatively tough, will sometimes remain entire when the included fibrils are ruptured by stretching the fibre, as represented in fig. LXII. In this way its existence may be demonstrated; and it is especially well seen in fish and other animals which have large fibres, for in these it is thicker and stronger. It may also be well shown in fresh muscular fibres from the frog, by exposing them to water under the microscope. The fluid is imbibed and then collects between the substance of the fibre and its sheath so as to separate the membrane and make it apparent. At the same time, as regards mammalian muscles, it must be admitted that it is not always easy to bring the sarcolemma distinctly into view.

Fig. LXI.

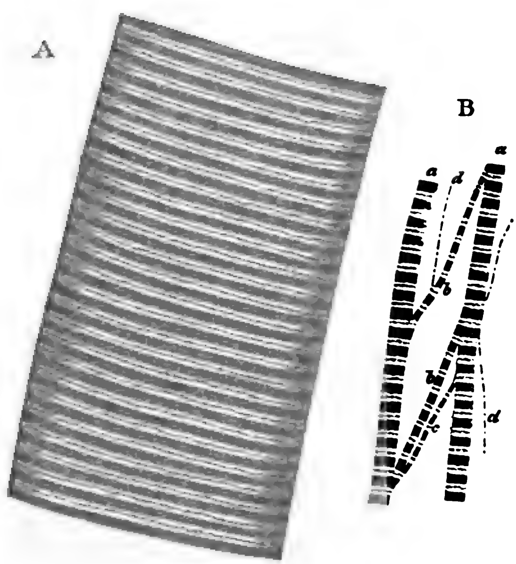


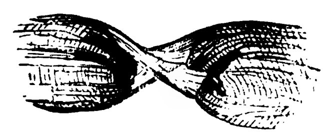
Fig. LXI. A. Portion of a medium-sized Human Muscular Fibre, magnified nearly 800 diameters.

B, *Separated bundles of Fibrils*, equally magnified. *a*, *a*, larger, and *b*, *b*, smaller collections; *c*, still smaller; *d*, *d*, the smallest which could be detached, possibly representing a single series of sarcous elements.

Fibrils.—Lines and fissures are sometimes seen running lengthwise in the substance of the fibres, and indicating their fibrillar structure, as in some of those represented in fig. LX.; and when these longitudinal lines are well marked, the transverse striæ are comparatively indistinct. In a thin transverse section the ends of the fibrils may be seen, when highly magnified, as small dots or points, which occupy the whole sectional area of the fibre, showing plainly that the latter is not hollow, as has sometimes been maintained, but possesses the same fibrillar structure throughout its whole thickness. The fibrils are closely connected together in the fibre by an inter-

mediate pellucid substance in very sparing quantity; they may be partially separated and spread out by breaking across a fibre, and gently bruising the broken end, as at *c* (fig. LX.), or by splitting up its substance with fine needles; and the separation is facilitated by previous immersion of the muscle for some time in alcohol or in a weak solution of chromic acid, which either strengthens the fibrils, or, by acting on the uniting substance, weakens their lateral cohesion. But whilst in this way the fibrillar structure is made apparent, and the fibre may be split up into fine bundles or skeins of fibrils (fig. LXI. B), and threads apparently single may be detached, yet it is by no means easy to say when we thus arrive at an insulated ultimate fibril. A thread so separated (fig. LXI. B, *c*) when viewed in proper focus with a magnifying power of 400 or 600, appears to consist of a row of dark quadrangular particles, named *sarcous elements* by Mr. Bowman, with bright intervals between them, as if they were connected by some pellucid substance of less refractive power. For the most part also a dark line may be discovered passing across the middle of each bright space. I am disposed, however, to think that the filaments thus described consist of more than one ultimate fibril; for I have now and then seen in specimens of human muscle treated with chromic acid, a finer filament (as at *d*, fig. LXI.) lying alongside one or more of those above described, and, whether itself an ultimate fibril or not, showing at least that those with the quadrangular particles are composite. In such a fine fibril the dark sarcous elements, whilst agreeing in length with those alongside, are slender, rod-shaped, or linear in figure; and in the middle of the bright intervals between them there is a dark point. In short the fibril looks like a line regularly broken at short distances, with a dot in each of the breaks. From this it may be inferred that the greater breadth of the quadrangular particles is caused by the lateral apposition of several rod-shaped particles; and it is plain that the appearance of a dark line in the bright interval is produced by a transverse range of the intervening dots.

Fig. LXII.



This account corresponds very much with what is seen on a larger scale in the muscular fibres of insects, by which I do not mean the fine, naturally separated, fibres of the thoracic muscles, sometimes taken for fibrils, but the larger fibres, in which fibrils answering to the above description are readily separable. In these, the rather long rod-shaped sarcous elements, of which the fibrils consist, give a fluted character to the broad cross stripes or bands which, by mutual apposition, they produce in the fibre (fig. LXIII).

The intermediate dotted line was long since noticed by Busk and Huxley, and was considered by them to be produced, most probably, by the interposition of a row of minute sarcous elements; but, as they justly observe, it is not invariably present.

Cause of the stripes, and cleavage into disks.—When the fibrillæ lie undisturbed in the fibre, the elementary particles of collateral fibrils are situated in the same transverse plane, and it is to this lateral coaptation of the particles that the transverse striping of the fibre is due. (See fig. LXIV.) Accordingly, the cross stripes are not confined to the surface of the fibre, but may be seen throughout its entire thickness on successively deepening the focus of the microscope. The fibres, moreover, when treated with certain reagents (such as very dilute hydrochloric acid), show a tendency to

cleave across in a direction parallel to these stripes, and even break up into transverse plates or disks, which are formed by the lateral cohesion of the particles of adjacent fibrils. To make up such a disk, therefore, every fibril contributes a particle, which separates from those of its own fibril, but coheres with its neighbours on either side, and this with perfect regularity. Indeed, Mr. Bowman conceives that the subdivision of a fibre into fibrillæ is merely a phenomenon of the same kind, only of more common occurrence, the cleavage in the latter case taking place longitudinally instead of transversely: accordingly, he considers that the fibrillæ have no existence as such in the fibre, any more than the disks; but that both the one and the other owe their origin to the regular arrangement of the particles of the fibre longitudinally and transversely, whereby, on the application of a severing force, it cleaves in the one or in the other direction into regular segments.

Fig. LXIII.

B A

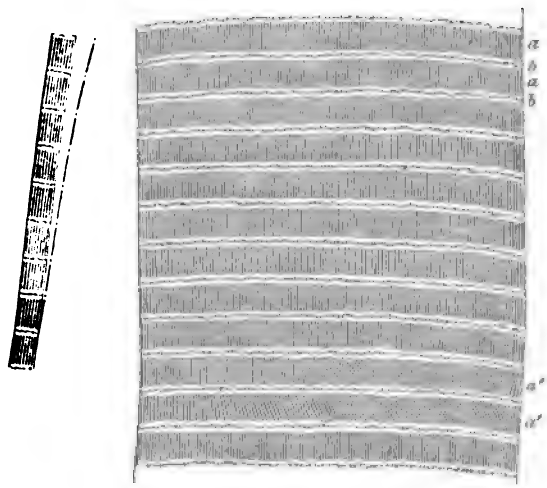


Fig. LXIII. A.—Portion of a (rather small sized) Muscular Fibre, from a Water Beetle, magnified 730 diameters.

a, *a*, dark cross bands formed by the apposition of slender rod-shaped sarcous elements; *b*, *b*, light stripes with intermediate line of dark specks; at *a'*, *a'*, inclined position of rods, as here and there seen. B, *a detached bundle of fibrils* equally magnified. On one side an apparently single series of elongated sarcous elements, with intermediate dots, possibly a single fibril.

Fig. LXIV.

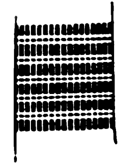


Fig. LXIV.—Diagram to show how the Stripes of Muscular Fibre are produced.

While some consider that the fibrils are composed throughout of the same substance, and that the alternation of dark and light portions is due to unimportant modifications of it, others believe that the light and dark parts differ essentially in nature. In proof of this Brücke adduces observations to show that the dark parts, or sarcous elements, doubly refract the light (or are "anisotropic"), whilst the intermediate light substance is singly refractive ("isotropic"). Moreover, as the sarcous elements and the dark stripes formed by them are variable in size and position—the stripes being sometimes broad and widely apart, at other times narrow and closer together—Brücke infers that the dark, doubly-refracting, or anisotropic substance consists of an aggregation of undistinguishably minute, doubly-refracting molecules, named by him *disdiaclasts*, imbedded in the isotropic matter; which, by grouping together in various numbers and modes, give rise to the variations in the size, figure, and arrangement of the sarcous elements. In reference to this view I may observe that while it

is easy to see that the muscular fibres are doubly refractive, and while the light and dark parts most probably differ in certain physical and chemical properties, it is not so clearly made out that the doubly refracting property is confined to the one of them.

Nuclei, or muscle-corpuscles.—A number of pale, finely granular, *oval* corpuscles, resembling cell-nuclei, are found in the fibres. In mammalian muscles they lie upon the inner surface of the sarcolemma, but in frogs they are distributed through the substance of the fibre (fig. LXV.). These have been supposed to be connected with the growth and nutrition of the muscle. They are obvious in the fœtus some time before birth, but afterwards the addition of acetic acid is usually required in order to render them visible. They are probably nuclei pertaining to the elongated cells in which the substance of the fibres is originally developed; and a small amount of granular matter which is not uncommonly collected around them has been regarded as a remnant of the formative protoplasm. Other corpuscles, mostly fusiform, but varying in shape, and having the character of connective-tissue corpuscles, lie here and there outside the sarcolemma, and doubtless belong to the interposed connective tissue.

Fig. LXV.

Fig. LXV.—A Frog's Muscular Fibre treated with Acetic Acid, magnified 350 diam. (from Kölliker).

The nuclei are somewhat shrunk. Interstitial granules in longitudinal rows, here and there, but these are mostly indistinct from compression and appear as mere lines.

Interstitial granules. — Different observers, and especially Kölliker, have described fine granules disposed in rows between the fibrils or smaller bundles of fibrils, as of frequent occurrence in the muscular fibres of man and animals (fig. LXVI.). They have been especially noted in the heart, and although they do not naturally show the characters of fat, it has been presumed that they may by conversion give rise to the fatty degeneration of muscular tissue. I must confess that I have not been able to perceive these granules in healthy human voluntary muscle.

Length and ending of the fibres.—The fibres composing a muscle are of limited length, not exceeding one inch and a half; and accordingly in a long fasciculus a fibre does not reach from one tendinous attachment to the other, but ends with a tapering pointed extremity, invested with its sarcolemma, and cohering with neighbouring fibres. Unless when either is fixed to a tendon, both extremities of the fibre terminate in the way described, so that it has a long fusiform shape.

Branched fibres.—Generally speaking, the fibres neither divide nor anastomose; but this rule is not without exception. Branched and anastomosing fibres are common in the heart (fig. LXXII.); in the tongue of the frog the muscular fibres (fig. LXVII.) as they approach the surface divide into numerous but not anastomosing branches, by which they are attached to the under surface of the mucous membrane. The same thing has also been seen in the tongue of man and many other animals; and the fibres of the facial muscles of mammals have been shown by Busk and Huxley to divide in a similar manner where they fix themselves to the skin.

Connection with tendons.—According to Professor Kölliker the mode of

connection differs when the muscular fibres are continuous in a direct line with those of the tendon from that which is observed when the former join the latter at a more or less acute angle. In the first case, the two are directly continuous, the muscular fibre being distinguishable from that of the fibrous tissue by its striation alone. In the second case, the muscular fibres terminate in conical processes, which are received in corresponding

Fig. LXVI.

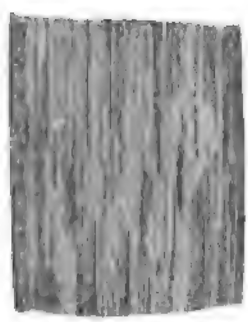


Fig. LXVII.

Fig. LXVI.—Frog's Muscular Fibre, showing Interstitial Granules, magnified 350 diam. (from Kölliker).

Fig. LXVII.—A Branched Muscular Fibre from the Frog's Tongue, magnified 350 diam. (from Kölliker).

depressions of the tendinous structure, to which they cling; the connective tissue of the one being continuous with that of the other. Weismann, who adopts this view on later observations of his own, states that the sarcolemma surrounds the ends of the fibres, which are not continuous with but rather, as it were, cemented to the tendon. Mr. Ellis, on the other hand, describes the connection of striated muscle with tendon as taking place in all cases in the following manner. When a muscular fibre is about to end in a tendon, its component fibrils are collected into bundles of different lengths and sizes like the roots of a tree. Around each bundle tendinous tissue is collected, forming a sheath which appears gradually to cease as it is continued backwards on the undivided fibre. The muscular fibrils of a bundle in approaching the tendon gradually cease, each having probably its own tendinous thread to fix it. The central bundles of fibrils reach further than the circumferential, and thus when the latter are broken off by attempts made to detach a fibre from its neighbours, the fibre appears to have a pointed ending. In this case also Weismann maintains that the sarcolemma intervenes between the muscular substance and the tendon.

Mr. Ellis does not confirm Professor Kölliker's account of the oblique mode of attachment. He states that in such instances as the gastrocnemius and soleus, every fibre is provided with its separate tendon and is continuous with it as above described, and that the increasing thickness of the main tendon from above downwards is due to successive additions, in form of strata, of the contributing tendons from the lower placed layers of muscular fibres; and this explanation is supported by subsequent observations of Fick, Margo, and Frey. In attaching themselves to the skin and mucous membranes, the muscular fibres, according to the careful description of Dr. Salter, divide into pointed processes or fine filaments which are continuous with those of the connective tissue.

Blood-vessels.—The blood-vessels of the muscular tissue are extremely abundant, so that, when they are successfully filled with coloured injection, the fleshy part of the muscle contrasts strongly with its tendons. The arteries, accompanied by their associate veins, enter the muscle at various points, and divide into branches; these pass among the fasciculi, crossing over them, and dividing more and more as they get between the finer divisions of the muscle; at length, penetrating the smallest fasciculi, they end in capillary vessels which run between the fibres. The vessels are supported in their progress by the subdivisions of the sheath of the muscle, to which also they supply capillaries. The capillaries destined for the proper tissue of the muscle are extremely small (fig. LXVIII.), they form among the fibres a fine network, with narrow oblong meshes, which are stretched out in the direction of the fibres: in other words, they consist of longitudinal and transverse vessels, the former running parallel with the muscular fibres, and lying in the angular intervals between them,—the latter, which are much shorter, crossing between the longitudinal ones, and passing over or under the intervening fibres.

Fig. LXVIII.

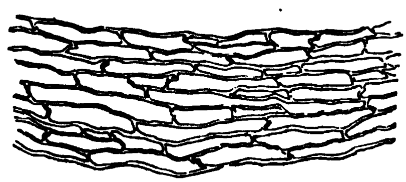


Fig. LXVIII.—Capillary Vessels of Muscle, from an Injection by Lieberkühn, seen with a low magnifying power.

The specimen was preserved in spirits; when the muscle is dried, the vessels appear much closer.

None of the capillary vessels enter the sarcolemma or proper sheath of the fibre, and the nutritious fluid which they convey must therefore reach the finer elements of the muscle by imbibition. Moreover, as the capillaries do not penetrate the fibres, but lie between them, their number in a given space, or their degree of closeness, will in some measure be regulated by the number and consequently by the size of the fibres; and accordingly in the muscles of different animals it is found that when the fibres are small, the vessels are numerous and form a close network, and *vice versâ:* in other words, the smaller the fibres, the greater is the quantity of blood supplied to the same bulk of muscle. In conformity with this, we see that in birds and mammalia, in which the process of nutrition is active, and where the rapid change requires a copious supply of material, the muscular fibres are much smaller and the vessels more numerous than in cold-blooded animals, in which the opposite conditions prevail.

Lymphatics.—Of lymphatic vessels in the muscular tissue nothing certain is known. From an examination of the lymphatics which appear to proceed

from different muscles, Kölliker infers that small muscles are destitute of such vessels, and that the few which apparently issue from some of the larger muscles, belong to the sheath and its larger subdivisions, and not to the proper muscular tissue.

Nerves.—The nerves of a voluntary muscle are of considerable size. Their branches pass between the fasciculi, and repeatedly unite with each other in form of a plexus, which is for the most part confined to a small part of the length of the muscle or muscular division in which it lies. From one or more of such *primary* plexuses, nervous twigs proceed and form finer plexuses composed of slender bundles, containing not more than two or three dark-bordered nerve fibres each, whence single fibres pass off between the muscular fibres and divide into branches which are finally distributed to the tissue. The mode of final distribution will be described with the general anatomy of the nerves.

Nerves of small size accompany the branches of blood-vessels within muscles, but do not reach the capillaries; though destined for the vessels these nerves sometimes communicate with the proper muscular plexuses.

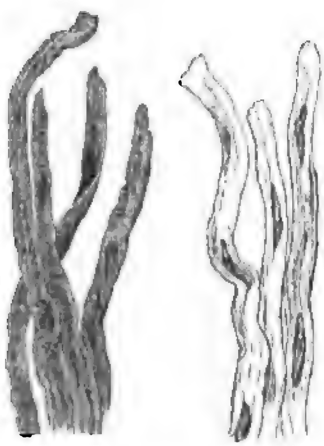
Involuntary muscles.—The involuntary muscular tissue differs from the voluntary kind, not only in its want of subjection to the will, but also in its external characters; for whilst in many parts it appears in the form of fibres, these, except in the heart and a few instances of less note, are unmarked by the cross lines so characteristic of the striped fibres; moreover, they are in reality made up of elongated contractile cells cemented together by some kind of uniting medium.

Plain or unstriped muscular tissue (fig. LXIX.).—This is generally of a pale colour. The fibres are for the most part roundish or prismatic, but are readily flattened in examination. Some are not above $\frac{1}{7000}$ of an inch in diameter; but the larger measure from $\frac{1}{4500}$ to $\frac{1}{3500}$ (Ellis). Under the microscope they have a peculiar soft aspect, without a strongly-shaded border; and they are marked at short intervals with oblong corpuscles, which give them a very characteristic appearance, especially after the application of acetic acid, which renders the corpuscles much more conspicuous. The substance of the fibres is translucent, but clouded or finely granular; and in the latter case the granules are sometimes arranged in longitudinal lines. There is no sarcolemma. These fibres, as already said, are made up of cells, named *contractile fibre-cells*, which were first distinguished as the true elements of the tissue by Kölliker. The cells may form fibres, bundles, and strata, or may be less regularly arranged, or mixed with other tissues in greater or less proportion. They are of an oblong flattened shape (figs. LXX. and LXXI), usually pointed at the ends, but sometimes abruptly truncated, and varying greatly in length according to the part or organ in which they are found. Some occur which are cleft or forked at one end. They measure for the most part from $\frac{1}{500}$ to $\frac{1}{300}$ of an inch or more in length. Their substance is finely granular and sometimes faintly striated, and, with few exceptions, no distinction is visible between envelope and contents. Each has a nucleus (*a*, *a*), rarely more than one, which is always elongated and either oval or rod-shaped. Accordingly the nuclei of the fibres above described belong to the constituent cells. By macerating the tissue in nitric acid diluted with four times its weight of water, the separation of the cells is greatly facilitated.

It is proper to state that a different view of the structure of the plain muscular tissue is entertained by some authorities. Mr. Ellis, after a very extended inquiry,

has arrived at the conclusion that it consists of fibres, which are not made up of the cells described, but agree in essential structure with those of voluntary muscle; and he considers the so-called nuclei as corpuscles belonging to the investing tissue of the

Fig. LXIX.



A B

Fig. LXIX.—Plain Muscular Fibres from the Human Bladder, magnified 250 diameters.

A, in their natural state; B, treated with acetic acid to show the corpuscles.

Fig. LXX.

Fig. LXXI.

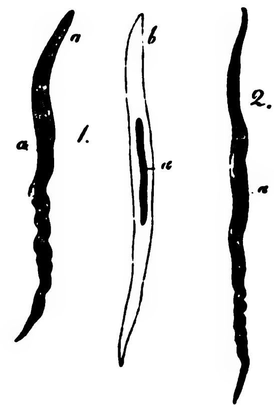


Fig. LXXI.—Muscular Fibre-Cells from Human Arteries, magnified 350 diameters (Kölliker).

a, natural state; *b*, treated with acetic acid.

Fig. LXX.—Muscular Fibre-Cell from the Muscular Coat of the Small Intestine, magnified (Kölliker).

muscular fibres. Without denying that there may be a modification or variety of the non-striated muscular fibres not divisible into singly nucleated cells, I nevertheless think that the existence of such contractile cells must now be admitted as fully established, and that the fibres and bundles of the plain muscular tissue are commonly made up of these cells.

The plain muscular tissue is for the most part disposed between the coats of the membranous viscera, as the stomach, intestines, and bladder, in the parietes of the air tubes, excretory ducts of glands, and the like. It is generally collected into larger and smaller fasciculi, which in many cases cross one another and interlace. The fasciculi are connected at their ends with tendinous tissue, and are thus inserted into the membranous and

firmer parts in the neighbourhood. Small tendons are also fixed by blending with the fibrous sheaths investing contiguous muscular bundles. In the gullet Mr. Ellis has found that the longitudinal muscular fasciculi are intersected wholly or partially, at intervals of from $\frac{1}{20}$ to $\frac{1}{10}$ of an inch, by small tendons into which they are inserted, after the fashion of the rectus abdominis, only on a miniature scale, and he thinks it probable that this disposition may exist in other parts.

The plain muscular tissue is met with in the lower half of the gullet, the stomach, and the whole intestinal canal; that is, both in the muscular coat of the alimentary canal, and also as a layer in the tissue of the mucous membrane, and in the villi; in the trachea and bronchial tubes, in the bladder and ureters and the ducts of the larger glands generally, in the uterus and its appendages, in the corpora cavernosa of both sexes, in the prostate gland, and in the ciliary muscle and iris. The middle coat of the arteries, the coats of many veins and the larger lymphatics contain plain muscular tissue. It has also been detected in certain parts of the skin, in the dartos or subcutaneous tissue of the scrotum, and in form of minute muscles attached to the hair-follicles.

Fig. LXXII.

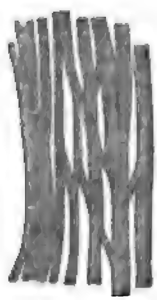


Fig. LXXII.—Muscular Fibres from the Heart, magnified, showing their cross-striæ, divisions and junctions (from Kölliker).

Muscular tissue of the heart.—The fibres of the heart differ remarkably from those of involuntary muscular organs in general, inasmuch as they present transverse striæ. The striæ, however, are less strongly marked, and less regular, and the fibres are smaller in diameter than in the voluntary muscles. Many of the fibres are attached to the tendinous structure connected with the orifices and valves, and as has been already stated, they are seen to divide and anastomose (fig. LXXII). The tissue of the heart differs also from most other involuntary muscular structures by its deep colour, but it agrees with them in the interlacement of its fasciculi.

Development of muscle.—The form-elements of the plain or unstriped muscular tissue are derived from embryonic nucleated cells, consisting of granular protoplasmic substance, as usual. These become lengthened out, pointed at the ends, and flattened, with elongation of the nucleus, whilst their substance becomes more uniform in aspect, and acquires its permanent condition and characteristic properties.

The striated muscular tissue is also developed in the embryo from cells. Schwann considered each fibre to be formed by the linear coalescence of several cells; and this opinion is still maintained by some authorities. Recent researches, however, for the most part, tend to establish the view originally, I believe, promulgated by Remak, viz., that the fibres are produced by the elongation of single cells, with differentiation of their contents and multiplication of their nuclei; and Dr. Wilson Fox, who has quite lately investigated the process in the tadpole, the chick, and the mammalian embryo, at very early stages, has arrived at the same conclusion.* Dr. Fox finds that the first elements of the muscular fibres are rounded or oval cells, with a clear nucleus and granular contents, agreeing in all respects with the cells of which the parts of the embryo body originally consist. To form a muscular fibre, a cell elongates, often with pointed ends; the nucleus

* Phil. Trans. 1866, p. 101.

generally divides into two, and by further division these are multiplied; a fine membrane, at first absent or invisible, is soon discovered, bounding the cell and inclosing its contents. In the mean time the substance becomes striated longitudinally at one part, and more transparent, the granules disappearing. The striation, which is the first indication of the proper muscular substance, extends throughout the length of the elongated cell, but at first affects only a small part of its breadth, and the remaining space is occupied by unchanged granular matter and the nucleus or nuclei which lie on one side. In due time, however, this conversion into the proper muscular substance, further shown by the appearance of cross striæ, proceeds through the whole thickness of the cell, or fibre as it may now be called; the inclosing cell-membrane becomes the sarcolemma, and the nuclei, with a small residue of the granular protoplasm still adhering to them, remain.

Fig. LXXIII.

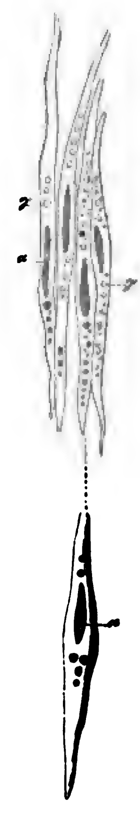


Fig. LXXIII.—Muscular Fibre-Cells from the Uterus, three Weeks after Delivery. The upper four treated with Acetic Acid, magnified 350 diameters (from (Kölliker).

a, nuclei; γ, fat granules.

Growth of muscles.—The muscular fibres of the growing fœtus, after having acquired their characteristic form and structure, continue to increase in size till the time of birth, and thenceforward up to adult age. In a full grown fœtus most of them measure twice, and some of them three or four times their size at the middle of fœtal life; and in the adult they are about five times as large as at birth. This increase in bulk of the individual fibres would, of course, so far account for the concomitant enlargement of the entire muscles. But there would seem to be also a multiplication of the fibres; and Budge believes he has proved this as regards the muscles of frogs. Two modes of production of new fibres have been described—viz. first, from connective tissue corpuscles lying between the existing fibres, by a process analogous to the original development of the muscle (von Wittich); secondly, by the splitting up of a fibre through its whole length into two or more smaller ones; preceded by multiplication of its included nuclei. This second process has been observed by Weismann and by Kölliker in frogs, in the winter season, and appears to serve for the replacement of fibres destroyed by fatty degeneration, which is said to be not uncommon in these creatures. Dr. Beale, however, denies that the new and slender fibres are derived from an old and larger one by splitting of its substance; he believes that they are produced from cells, as in the first mode, and that the old fibre is removed. The great increase in the muscular tissue of the uterus during gestation takes place both by elongation and thickening of the pre-existing fibre-cells of which that non-striated tissue consists, and by the development of new muscular fibre-cells from small, nucleated, granular cells lying in the tissue. In the shrinking of the uterus after parturition the fibre-cells also shrink to their previous size; many of them become filled with fat granules (fig. LXXIII.), and many are doubtless removed by absorption.

As far as can be concluded from the observations and experiments that have hitherto been made on the subject, the striated muscular tissue is not regenerated in warm-blooded animals. It is true, that when a muscle is cut across, or a portion removed, the breach will heal, but the loss of substance is not repaired by new-formed muscular tissue. Striated muscular fibres have been found in certain tumours of the ovary and testicle, but these cases are altogether peculiar and abnormal.

Chemical composition of muscle.—Muscular tissue contains nearly 80 per cent. of water, so that in being dried it loses about four-fifths of its weight. The chief and characteristic constituent of the fibre is an albuminoid body. This was at one time regarded as fibrin; but, as it was afterwards shown to be not identical with that substance, it was distinguished by the name of *syntonin*; the grounds of distinction being, that syntonin is soluble in very dilute hydrochloric acid, and can be extracted from muscle by that solvent; also, that its solution is precipitated by neutral salts. More recently, the subject has been investigated by Kühne, who maintains that the albuminoid matter of muscle exists in the fibres in a liquid form during life, but coagulates after death, and thereby gives rise to the cadaveric rigidity which then invades the muscles. When extracted from fresh and still irritable frogs' muscles at a temperature of freezing, this substance, which Kühne names *myosin*, is liquid; but if it be then exposed to the ordinary heat of the atmosphere it partially coagulates, and the portion then remaining liquid (the *muscle serum*) when heated to 112° F., or less if it be strongly acid, yields a further coagulum, which Kühne considers peculiar to muscle; and finally, at 167°, ordinary coagulated albumen. The primary coagulation is hastened by the presence of blood, and possibly it may be due to the mutual reaction of two albuminoids analogous in their operation to the fibrinogen and fibrinoplastin (or globulin) of the blood (antea, p. xxxviii.). The coagulum of myosin is soluble in strong solutions of neutral salts, and accordingly it may thereby be dissolved out of dead and rigid muscles; but it loses this property if previously dissolved in dilute hydrochloric acid. It then, in fact, agrees with the so-called syntonin, which Kühne regards, not as an original albuminoid of muscle, but as myosin altered by the process of extraction. It has been suggested that the ready solution of muscular fibre in dilute hydrochloric acid may be owing to the presence of pepsine in minute quantity.

Other organic compounds also exist in muscle, but in very small proportion in comparison with the albuminoid matter. Most of them probably result from the process of wear of the original muscular substance. Among the most notable are,—1. Kreatin and Kreatinine, both of them nitrogenized and crystalline, the former neutral, the latter (derived from it), alkaline; both are also found in the urine. 2. Sarkin (or Hypoxanthin). 3. Non-nitrogenized substances, viz.: grape sugar; inosit—an unfermentable sugar from the tissue of the heart; glycogen, at least in embryos and young animals. 4. Various organic acids, viz., lactic, inosinic, butyric, acetic, formic and uric. 5. Salts, in which potash predominates over soda, magnesia over lime, and phosphoric acid over chlorine,—muscle, in this respect, resembling blood-corpuscles as contrasted with serum. Lastly, a variable amount of fat may be extracted from muscle, and also gelatin; the latter no doubt from connective tissue; for it must be remembered that a piece of muscle subjected to analysis comprehends, along with the proper muscular fibres, more or less of connective tissue, blood-vessels and nerves. The account here given of the chemical constitution of muscle applies

especially to the striped variety, but, so far as is known, it is essentially the same in the non-striated tissue.

The juice expressed from a muscle after death, and especially after rigidity has set in, is acid, from the presence of lactic acid; so that the cut surface of a dead muscle reddens litmus-paper. On the other hand, a perfectly fresh section of muscle in the living body, or while it retains its irritability, is alkaline or neutral. But while this is true of a living muscle in its usual state, it gives a decided acid reaction after it has been strongly exerted, as, for instance, after tetanic spasm excited by electricity or by strychnia poisoning. The acid is probably generated by a change in the saccharine matter of the muscle. Ultimately the tissue in all cases becomes alkaline from putrefaction and the evolution of ammonia.

Physical properties of muscle.—A dead muscle has little strength, and may be torn asunder by a force of no great amount. A living muscle readily yields to extension, and shrinks exactly to its original length when the extending force ceases. Its elasticity is therefore said to be small in degree, but very perfect or complete in operation. A dead muscle, especially after cadaveric rigidity has come on, resists extension more powerfully, but does not afterwards return to its original length; hence its elasticity is said to be greater than that of the living muscle, but less perfect.

The red colour of muscle is well known, but it differs greatly in degree in different cases. It is usually paler in the involuntary muscles; but here the heart again is a striking exception. In most fish the chief muscles of the body are nearly colourless, and in the breast of wild fowl we see a difference in the depth of colour in different strata of the same muscles. The redness is no doubt partly due to blood contained in the vessels, but not entirely so, for a red colouring matter, apparently of the same nature as that of the blood, is obviously incorporated with the fibres.

Under this head must also be mentioned the manifestation of electricity by a quiescent but living muscle. When a muscle taken from a living or recently killed animal (a frog is commonly used) is brought into connection with the ends of a very delicate galvanometer, so that one extremity of the latter touches the outer surface of the muscle, and the other a cross section made through its fibres, the needle will deviate so as to indicate an electric current passing along the wire from the surface of the muscle to its cross section. If both ends of the galvanometer touch points in the length of the muscle equidistant from its middle, no effect ensues, but if one point of contact be farther than the other from the middle, a current will pass along the wire from the nearer to the more distant point. The same results are obtained with a small shred or fasciculus of the muscle. The phenomenon described is called "the muscular current," and is supposed to indicate a state of electric polarity in the particles of the muscle, probably caused by chemical changes going on in its substance.

Vital properties of muscle.—The muscular tissue possesses a considerable degree of *sensibility*, but its characteristic vital endowment, as already said, is *irritability* or *contractility*, by which it serves as a moving agent in the animal body.

Sensibility.—This property is manifested by the pain which is felt when a muscle is cut, lacerated, or otherwise violently injured, or when it is seized with spasm. Here, as in other instances, the sensibility belongs, properly speaking, to the nerves which are distributed through the tissue, and accordingly when the nerves going to a muscle are cut, it forthwith becomes insensible. It is by means of this property, which is sometimes called the "muscular sense," that we become conscious of the existing state of the muscles which are subject to the will, or rather of the position and direction of the limbs and other parts which are moved through means of the voluntary muscles, and we are thereby guided in directing our voluntary movements towards the end in view. Accordingly, when this muscular sense is lost, while the power of motion remains,—a case which, though rare, yet sometimes occurs,—the person cannot direct the movements of the affected limbs without the guidance of the eye.

Irritability or Contractility.—The merit of distinguishing this property of the animal body from sensibility on the one hand, and from mere mechanical phenomena on the other, is due to Dr. Francis Glisson, a celebrated English physician of the seventeenth century; but irritability, according to the view which he took of it, was supposed to give rise to various other phenomena in the animal economy besides the visible contraction of muscle, and his comprehensive acceptation of the term has

been adopted by many succeeding authorities, especially by writers on pathology. Haller, in his use of the term irritability, restricted it to the peculiar property of muscle.

Stimuli.—In order to cause contraction, the muscle must be excited by a stimulus. The stimulus may be applied immediately to the muscular tissue, as when the fibres are irritated with a sharp point; or it may be applied to the nerve or nerves which belong to the muscle: in the former case, the stimulus is said to be "immediate," in the latter, "remote." The nerve does not contract, but it has the property, when stimulated, of exciting contractions in the muscular fibres to which it is distributed, and this property, named the "vis nervosa," is distinguished from contractility, which is confined to the muscle. Again, a stimulus may be either directly applied to the nerve of the muscle, as when that nerve is itself mechanically irritated or galvanised; or it may be first made to act on certain other nerves, by which its influence is, so to speak, conducted in the first instance to the brain or spinal cord, and then transferred or reflected to the muscular nerve.

The stimuli to which muscles are obedient are of various kinds; those best ascertained are the following, viz.: 1. Mechanical irritation of almost any sort, under which head is to be included sudden extension of the muscular fibres. 2. Chemical stimuli, as by the application of salt or acrid substances. 3. Electrical; usually by means of a galvanic current made to pass through the muscular fibres or along the nerve. 4. Sudden heat or cold; these four may be classed together as *physical stimuli*. Next, *mental stimuli*, viz.: 1. The operation of the will, or volition. 2. Emotions, and some other involuntary states of the mind. Lastly, there still remain exciting causes of muscular motions in the economy, which, although they may probably turn out to be physical, are as yet of doubtful nature, and these until better known may perhaps without impropriety be called *organic stimuli;* to this head may be also referred, at least provisionally, some of the stimuli which excite convulsions and other involuntary motions which occur in disease.

Duration of irritability after death.—It is known that if the supply of nutrient material be cut off from a muscle by arresting the flow of blood into it, its contractility will be impaired, and soon extinguished altogether, but will, after a time, be recovered again if the supply of blood be restored. The influence of the blood supplied to muscles in maintaining their contractility has been strikingly shown by Dr. Brown-Séquard, who has succeeded in restoring muscular contractility in the bodies both of man and animals some time after death, and after it had become to all appearance extinct, by injecting into the vessels arterial blood deprived of its fibrin, or defibrinated venous blood previously reddened by exposure to the air. In warm-blooded animals in which the nutritive process is more active, and the expenditure of force more rapid, the maintenance of irritability is more closely dependent on the supply of blood and the influence of oxygen, so that it sooner fails after these are cut off. In accordance with this statement it is known that while the muscles of man and quadrupeds cease to be irritable within a few hours after death, and those of birds still sooner, the muscular irritability will remain in many reptiles and fish, even for days after the extinction of sensation and volition, and the final cessation of the respiration and circulation,—that is, after systemic death. A difference of the same kind is observed among warm-blooded animals in different conditions; thus irritability endures longer in new-born animals than in those which have enjoyed respiration for some time and are more dependent on that function; and in like manner, it is very lasting in hybernating animals killed during their winter sleep.

But the duration of this property differs also in different muscles of the same animal. From numerous careful observations Nysten concluded that in the human body its extinction takes place in the following order, viz.: 1, the left ventricle of the heart; 2, the intestines and stomach; 3, the urinary bladder; 4, the right ventricle; in these generally within an hour; 5, the gullet; 6, the iris; 7, the voluntary muscles, *a*, of the trunk, *b*, of the lower, and *c*, the upper extremities; 8, the left auricle, and, 9, the right auricle of the heart, which last was on this account styled by Galen the "ultimum moriens." In one case Nysten observed the right auricle to continue irritable for sixteen hours and a half after death. But it has been recently found that a voluntary muscle will give signs of a certain degree of

irritability even later than this, if it is struck a smart blow with a blunt edge, such as the back of a knife, across the direction of the fibres. The contraction then produced is quite local, and confined to the part struck. Funke states that he and the brothers Weber obtained this result in the body of a decapitated criminal twenty-four hours after death.

The time of duration is affected by the mode of death. Thus the irritability is said to be almost wholly and immediately extinguished by a fatal stroke of lightning, and to disappear very speedily in the bodies of persons stifled by noxious vapours, such as carbonic acid, and especially sulphuretted hydrogen. In like manner certain causes acting locally on muscles accelerate the extinction of their irritability.

Rigor mortis.—The "cadaveric rigidity," or stiffness of the body, which ensues shortly after death, is a phenomenon depending on the muscles, which become fixed or set in a rigid state, so as to resist flexion of the joints. The rigidity almost invariably begins in the muscles of the lower jaw and neck, then invades those of the trunk, and afterwards those of the limbs,—the arms usually before the legs. After persisting for a time, it goes off in the same order. It usually comes on within a few hours after death, rarely later than seven hours. In some cases it has been observed to begin within ten minutes (Sommer), and in others not till sixteen or eighteen hours; and the later its access, the longer is its endurance. The rigidity comes on latest, attains its greatest intensity, and lasts longest in the bodies of robust persons, cut off by a rapidly fatal disease, or suddenly perishing by a violent death; in such cases it may last six or seven days. On the other hand, it sets in speedily, is comparatively feeble, and soon goes off in cases where the body has been much weakened and emaciated by lingering or exhausting diseases; also in new-born infants, and in the muscles of animals that have been hunted to death. It seems thus to be affected by the previous state of nutrition of the muscles. Destruction of the nervous centres does not prevent the occurrence of rigidity, nor are the muscles of paralysed limbs exempted from it, provided their nutrition has not been too deeply affected. The fibres of stiffened muscles are less translucent than before, but no other change is discovered by the microscope. They no longer show the muscular electric current.

The immediate cause of the muscular rigidity is doubtful: some conceive it to be an effect of vital contraction,—the last effort of life as it were; others, with more probability, ascribe it to a solidification of the tissue caused by chemical changes occurring after death. Kühne adduces various arguments, some of them, it must be admitted, of a cogent character, to show that the stiffening is due to post-mortem coagulation of the myosine. He thinks that the substance of the fibre is liquid during life; but it is difficult to reconcile this notion of actual fluidity of substance with some of the most obvious properties of a living muscle. At the same time, it is conceivable that liquid myosin may be present in the interstices of more consistent elements of the living fibre, and may give rise to rigidity by coagulating after death. Free lactic acid is developed in the substance of rigid muscle, and some regard it as the cause of the coagulation of the myosin, but although an acid condition very generally accompanies rigidity, the concurrence is not invariable or essential. Dr. Brown-Séquard, in opposition to the chemical theory, maintained that he could remove rigidity by injecting blood into the vessels of the muscle; but Kühne holds this to be impossible after rigor has decidedly set in. The general accession of rigidity is an unequivocal sign of death.*

NERVOUS SYSTEM.

Of the functions performed through the agency of the nervous system, some are entirely corporeal, whilst others involve phenomena of a mental or psychical nature. In the latter and higher class of such functions are first to be reckoned those purely *intellectual operations*, carried on through the instrumentality of the brain, which do not immediately arise from an

* The subject of muscular contraction and other questions relating to the functional activity of muscle, treated of in former editions of this work, have outgrown the space that could be allotted to their consideration here, and as, moreover, they properly belong to a treatise on physiology, they have now been omitted.

external stimulus, and do not manifest themselves in outward acts. To this class also belong *sensation* and *volition*. In the exercise of sensation the mind becomes conscious, through the medium of the brain, of impressions conducted or propagated to that organ along the nerves from distant parts; and in voluntary motion a stimulus to action arises in the brain, and is carried outwards by the nerves from the central organ to the voluntary muscles. Lastly, *emotion*, which gives rise to gestures and movements varying with the different mental affections which they express, is an involuntary state of the mind, connected with some part of the brain, and influencing the muscles through the medium of the nerves.

The remaining functions of the nervous system do not imply necessary participation of the mind. In the production of those movements, termed *reflex*, *excited*, or *excito-motory*, a stimulus is carried along afferent nerve-fibres to the brain or spinal cord, and is then transferred to efferent or motor-nerve-fibres, through which the muscles are excited to action; and this takes place quite independently of the will, and may occur without consciousness. The motions of the heart, and of other internal organs, the contraction of the coats of the blood-vessels, as well as the invisible changes which occur in secretion and nutrition, are in a certain degree subject to the influence of the nervous system, and are undoubtedly capable of being modified through its agency, though, with regard to some of these phenomena, it is doubtful how far the direct intervention of the nervous system is necessary for their production. These actions, which are all strictly involuntary, are, no doubt, readily influenced by mental emotions; but they may also be affected through the nerves in circumstances which entirely preclude the participation of the mind.

The nervous system consists of a *central part*, or rather a series of connected *central organs*, named the *cerebro-spinal axis*, or *cerebro-spinal centre*; and of the *nerves*, which have the form of cords connected by one extremity with the cerebro-spinal centre, and extending from thence through the body to the muscles, sensible parts, and other organs placed under their control. The nerves form the medium of communication between these distant parts and the centre. One class of nervous fibres, termed *afferent* or *centripetal*, conduct impressions towards the centre,—another, the *efferent* or *centrifugal*, carry motorial stimuli from the centre to the moving organs. The nerves are, therefore, said to be internuncial in their office, whilst the central organ receives the impressions conducted to it by the one class of nerves, and imparts stimuli to the other,—rendering certain of these impressions cognisable to the mind, and combining in due association, and towards a definite end, movements, whether voluntary or involuntary, of different and often of distant parts.

Besides the cerebro-spinal centre and the nervous cords, the nervous system comprehends also certain bodies named *ganglia*, which are connected with the nerves in various situations. These bodies, though of much smaller size and less complex nature than the brain, agree, nevertheless, with that organ in their elementary structure, and to a certain extent also in their relation to the nervous fibres with which they are connected; and this correspondence becomes even more apparent in the nervous system of the lower members of the animal series. For these reasons, as well as from evidence derived from experiment, but which is of a less cogent character, the ganglia are regarded by many as nervous centres, to which impressions may be referred, and from which motorial stimuli may be reflected or emitted; but of local and limited influence as compared with the cerebro-spinal centre, and

operating without our consciousness and without the intervention of the will.*

The nerves are divided into the *cerebro-spinal*, and the *sympathetic* or *ganglionic* nerves. The former are distributed principally to the skin, the organs of the senses, and other parts endowed with manifest sensibility, and to muscles placed more or less under the control of the will. They are attached in pairs to the cerebro-spinal axis, and like the parts which they supply are, with few exceptions, remarkably symmetrical on the two sides of the body. The sympathetic or ganglionic nerves, on the other hand, are destined chiefly for the viscera and blood-vessels, of which the motions are involuntary, and the natural sensibility is obtuse. They differ also from the cerebro-spinal nerves in having generally a greyish or reddish colour, in their less symmetrical arrangement, and especially in the circumstance that the ganglia connected with them are much more numerous and more generally distributed. Branches of communication pass from the spinal and several of the cerebral nerves at a short distance from their roots, to join the sympathetic, and in these communications the two systems of nerves mutually give and receive nervous fibres; so that parts supplied by the sympathetic may be also in nervous connection with the cerebro-spinal centre.

The nervous system is made up of a substance proper and peculiar to it, with inclosing membranes, nutrient blood-vessels, and supporting connective tissue. The *nervous substance* has been long distinguished into two kinds, obviously differing from each other in colour, and therefore named the *white*, and the *grey* or *cineritious*.

CHEMICAL COMPOSITION.

The information we possess respecting the chemical composition of nervous matter is for the most part founded on analyses of portions of the brain and spinal cord; but the substance contained in the nerves, which is continuous with that of the brain and cord, and similar in physical characters, appears also, as far as it has been examined, to be of the same general chemical constitution. No very careful comparative analysis has yet been made of the grey and white matter, to say nothing of the different structural elements of the nervous substance; and indeed it must be remembered, that, in portions of brain subjected to chemical examination, capillary blood-vessels, connective, and perhaps other accessory tissues, as well as interstitial fluid, are mixed up in greater or less quantity with the true nervous matter, and must so far affect the result.

The nervous matter may be said to consist of an albuminoid body, in part liquid, with fatty principles, extractive matters, salts, and much water. The water, which forms from three-fourths to four-fifths or more of the whole cerebral substance, may be removed by immersion in alcohol and evaporation. When the solid matter which remains after removal of the water is treated with ether and hot alcohol, the fatty compounds are extracted from it by these menstrua, and there remains a mixture of coagulated albuminous matter and salts, with a small remnant due to accessory tissues, chiefly vessels.

The *albuminoid constituent* is not sufficiently known to be characterised specifically. It no doubt belongs, in some small proportion, to the interstitial fluid. Of that which

* From the researches of Dr. Augustus Waller it appears probable that ganglions exert some influence over the nutrition of the nerve-fibres connected with them, and serve to maintain the structural integrity of these fibres; for it has been found that when a ganglionic nerve is cut across in a living animal, the part beyond the section after a time becomes atrophied, while the part connected with the ganglion retains its integrity.

is contained in the proper nervous substance, a portion—forming the central part of the nerve fibres (axis cylinder)—appears in microscopic observations to be solid; whilst in the surrounding part (medullary sheath) the albuminoid is liquid and incorporated with fatty matter, also liquid, being probably combined as a colloid with the fat, in the way pointed out by Mr. Graham (see ante, page vii). The fats are—

1. The *cerebric acid* of Fremy, called *cerebrin* by Gobley, because he considers it a neutral body, acid only from contamination with phosphoric acid, but containing phosphorus, which also is regarded as an impurity by W. Müller.

2. *Oleo-phosphoric acid* of Fremy, a very unstable compound, held by Gobley to be a mixture of oleic acid and his glycero-phosphoric acid, which, it may be remarked, he has found also in the yelk of the egg.

3. *Olein*, *margarin*, and *palmitin*, with their acids.

4. *Cholesterin*—although this is no longer considered a true fat, and may, moreover, be a product of tissue change.

The extractive matters probably belong chiefly to the interstitial fluid; but, however this may be, they may be held to represent the products of decomposition of the nervous substance. The following have been recognised:—

1. *Lactic, formic, acetic*, and (traces of) *uric* acid.
2. *Inosit.*
3. *Kreatin.*
4. *Hypoxanthin* (or sarkin).
5. *Leucin* (in the ox).

In regard to free acid, Funke has found the same law to prevail in nerve as in muscle—namely, that the substance of nerves in the living but quiescent state is neutral, but becomes acid after death or prolonged excitement. The saline or inorganic matters found by incineration are—*phosphoric acid, phosphates of alkalies*, which, as in muscle, largely predominate over other salts, *potash*, as a base largely exceeding *soda; earthy phosphates*, in smaller proportion, *magnesia* prevailing over *lime; phosphate of iron; chloride of sodium, sulphate of potash*, and a trace of *silica*. From fresh brain-substance Breed obtained 0·027 per cent. of ashes, which per 100 parts yielded 55·24 phosphate of potash, 22·93 phosphate of soda, 1·23 phosphate of iron, 1·62 phosphate of lime, 3·4 phosphate of magnesia, 4·74 chloride of sodium, 1·64 sulphate of potash (the sulphuric acid doubtless from combustion of principles containing sulphur), 9·15 free phosphoric acid (from combustion of phosphorus), and 0·42 silicic acid.

The white substance contains nearly 75 per cent. of water; the grey about 85; the proportion of water is less in the spinal cord, and still less in the nerves. The fat amounts in the grey matter to nearly 5 and in the white to nearly 15 per cent.; in the nerves the proportion fluctuates largely. It is worthy of note that the brain during embryo and infantile life contains much less fat and more water; moreover, the grey and the white matter do not present the same differences as in after life in the proportions of water and fat which they respectively contain. The brain of embryos of from ten to twenty-two weeks has been found to yield only from 0·99 to 1·5 per cent. of fat; that of the full grown fœtus from 3 to 4 per cent. The water in the fœtal brain at birth is about 85 per cent., both in the white and the grey substance.

STRUCTURAL ELEMENTS.

When subjected to the microscope, the nervous substance is seen to consist of two different structural elements, viz., *fibres* and *cells*. The fibres are found universally in the nervous cords, and they also constitute the greater part of the nervous centres: the cells on the other hand are confined in a great measure to the cerebro-spinal centre and the ganglia, and do not exist generally in the nerves properly so called, although they have been found at the terminations of some of the nerves of special sense, and also interposed here and there among the fibres of particular nerves; they are contained in the grey portion of the brain, spinal cord, and ganglia, which grey substance is in fact made up of these cells intermixed in many parts with fibres, and with a variable quantity of supporting connective substance.

In further pursuing the subject, we shall first examine the fibres and cells by themselves, and afterwards consider the structure of the parts which they contribute to form, viz., the cerebro-spinal organs, the ganglia, and the nerves.

The fibres are of two kinds: 1, the *white*, *tubular*, *medullated*, or *dark bordered*, and 2, the *grey*, *pale*, *non-medullated*, or *gelatinous*. The former are by far the most abundant; the latter are found principally in the sympathetic nerve, but are known to exist also in many of the cerebro-spinal nerves.

The White or Tubular Fibres (fig. LXXIV).—These form the white part of the brain, spinal cord, and nerves. When collected in considerable numbers and seen with reflected light, the mass which they form is white and

Fig. LXXIV.

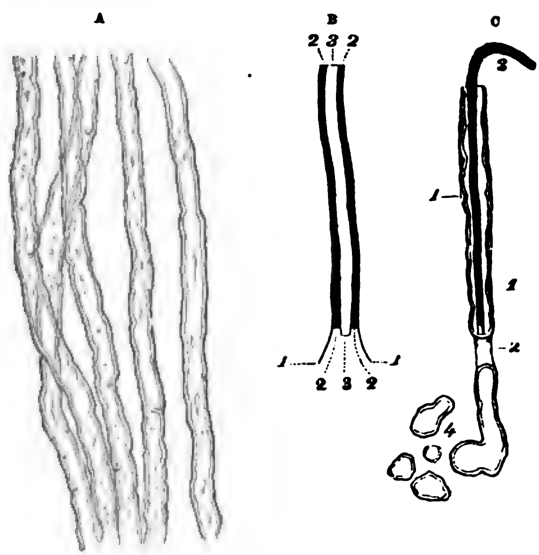


Fig. LXXIV.—A. White or Tubular Nerve-Fibres, showing the sinuous outline and double contours.

B. Diagram to show the parts of a tubular fibre, viz. 1, 1, *membranous tube.* 2, 2, *white substance* or *medullary sheath.* 3, *axis* or *primitive band.*

C. Diagram intended to represent the appearances occasionally seen in the tubular fibres. 1, 1, membrane of the tube seen at parts where the white substance has separated from it. 2, a part where the white substance is interrupted. 3, axis projecting beyond the broken end of the tube. 4, part of the contents of the tube escaped.

opaque. Viewed singly, or few together, under the microscope, with transmitted light, they are transparent; and if quite fresh from a newly-killed animal, and unchanged by cold or exposure, they appear as if entirely homogeneous in substance, like threads of glass, and are bounded on each side by a simple and usually gently sinuous outline. Their size differs considerably even in the same nerve, but much more in different parts of the nervous system; some being as small as the $\frac{1}{12000}$th and others upwards of the $\frac{1}{1500}$th of an inch in diameter; moreover, the same fibre may change its size in different parts of its course, and it is generally smaller at its central and peripheral ends. Very speedily after death, and especially on exposure to the action of water, these seemingly homogeneous fibres become altered:

and it is when so altered that they are commonly subjected to examination, as represented in fig. LXXIV A. In particular instances, and in favourable circumstances, it may be discovered that the fibre is composed of a fine membranous tube, inclosing a peculiar soft substance, and that this contained substance itself is distinguishable into a central part placed like a sort of axis in the middle of the tube, and a peripheral portion surrounding the axis, and occupying the space between it and the tubular inclosing membrane. In the annexed ideal plan (fig. LXXIV B), the *membranous tube*, or *primitive sheath*, is marked 1, 1 : the central part, marked 3, was named *cylinder axis* by Purkinje, who considered it to be identical with the structure previously described by Remak under the name of the *primitive band* (fibra primitiva) ; the matter surrounding it, marked 2, 2, is supposed to be the chief cause of the whiteness of the brain and nerves, and it was accordingly named the *white substance* by Schwann, and by others, though less appropriately, the *medullary sheath*. It is this last-mentioned substance which undergoes the most marked change on exposure ; it then seems to suffer a sort of coagulation or congelation, and when this has taken place, it very strongly refracts the light, and gives rise to the appearance of a dark border on each side of the nerve-tube (fig. LXXIV, A and C). This border, though darker than the rest of the tube, is nevertheless translucent, and is either colourless, or appears of a slightly yellowish or brownish tint ; it is bounded by two nearly parallel lines, so that the nerve-fibre has then a double contour, and the inner line, less regular than the outer, gradually advances further inwards as the change in the white substance extends to a greater depth. The dark contours pursue a sinuous course, often with deep and irregular indentations ; while straight or curved lines of the same character, occasioned no doubt by wrinkles or creases occurring in the layer of white substance, are frequently seen crossing the tube. By continued exposure, round and irregular spots appear at various points, and at length the contents of the nerve-tube acquire a confusedly curdled or granulated aspect.

The double contour appears only in fibres of a certain size; in very fine tubes, which become varicose or dilated at intervals, the double line is seen only in the enlargements, and not in the narrow parts between. It often happens that the soft contents of the tube are pressed out at the ruptured extremities, as in fig. LXXIV. C, 4, and then the round or irregular masses of the effused matter are still surrounded by the double line, which proves that this appearance is produced independently of the membranous tube. So long as this tube is accurately filled by the contained matter, its outline cannot be distinguished; but sometimes, when the white substance separates at various points from the inside of the tube, the contour of the fibre becomes indented and irregular, and then the membrane of the tube may, in favourable circumstances, be discerned as an extremely faint line, running outside the deeply-shaded border formed by the white substance, and taking no part in its irregular sinuosities (fig. LXXIV., C, 1, 1). The membranous tube may also be distinguished at parts where the continuity of the contained matter is broken in consequence of traction, squeezing, or like injury of the fibre; in such parts the double line produced by the white substance is wanting, and the faint outline of the membranous tube may be perceived passing over the interruption (2). The fine transparent membrane which forms this tube, named also the *primitive sheath*, appears to be quite simple and homogeneous in structure; so far as can be judged, it agrees in chemical nature with elastic tissue. Treatment with weak chromic acid, or iodine, or, still better, staining with carmine or aniline-red (magenta), brings into view nuclei attached along the sheath. They are found on the fibres of the nerves generally, but not in the optic and auditory nerves, nor in the brain and spinal cord; and, indeed, it is still a question whether the fibres of these last-named nerves and nervous centres are provided with a membranous sheath.

The *axis cylinder*, *axis band*, or *axial fibre* is situated in, or near, the middle of the nerve-tube, where it may occasionally be seen, on a careful inspection, as a greyish stripe or band, bounded on either side by a very faint, even outline, having no share in the sinuosities of the white substance (fig. LXXIV, C).

The axis is of a more tenacious consistence than the white substance, and may accordingly be sometimes seen projecting beyond it at the end of a broken nerve-tube, either quite denuded, or covered only by the tubular membrane, the intervening white substance having escaped. Although the name of axis-cylinder would seem to imply that it had actually a cylindrical figure, yet this is by no means certain; and whether naturally cylindrical or not, it certainly very generally appears more or less flattened when subjected to examination. To all outward appearance, usually, it is solid and homogeneous, but sometimes it is striated longitudinally, and towards its termination at the peripheral extremity of the nerve, it very commonly divides into finer filaments. The axis-cylinder consists of a solid albuminoid substance, whereas the medullary sheath or white substance consists mainly of fat and a certain proportion of albuminous matter, combined with it as a colloid into an oleo-albuminous liquid. Accordingly, whilst water, especially when cold, rapidly produces congelation of the white substance, ether, on the other hand, causes it speedily to disappear as if by solution, and globules of oil then make their appearance both within and without the tube, the remaining contents becoming granular from precipitation of albumen.

The existence of an axial fibre is probably universal in nerve-fibres, though it is not generally visible without preparation. To bring it into view, a solution of carmine or aniline-red (magenta) may be used, which stains it red—first colouring the denuded and projecting ends, but finally also the part still surrounded with the medullary sheath. Glacial acetic acid, chromic acid, iodine, alcohol, chloroform, collodium, and other reagents, are also employed with greater or less advantage.

Many of the tubular nerve-fibres, when subjected to the microscope, appear dilated or swollen out at short distances along their length, and contracted in the intervals between the dilated parts. Such fibres have been named *varicose* (fig. LXXV). They occur principally in the brain and spinal cord, and in the intracranial part of the olfactory, in the optic, and acoustic nerves; they are occasionally met with also in the other nerves, especially in young animals. These fibres, however, are naturally cylindrical like the rest, and continue so while they remain undisturbed in their place; and the varicose character is occasioned by pressure or traction during the manipulation, which causes the soft matter contained in the nerve-tube to accumulate at certain points, whilst it is drawn out and attenuated at others. Most probably the change takes place before the white substance has coagulated. The fibres in which it is most apt to occur are usually of small size, ranging from $\frac{1}{12000}$th to $\frac{1}{3600}$th of an inch in diameter; and when a very small fibre is thus affected, the varicosities appear like a string of

Fig. LXXV.

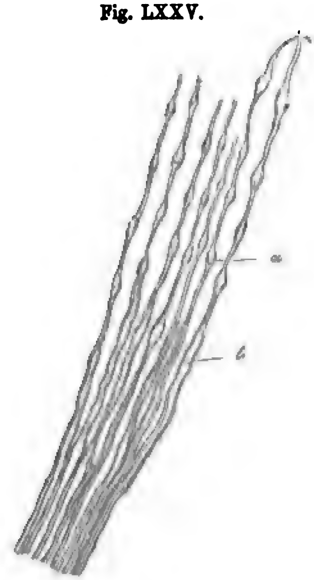


Fig. LXXV.—FIBRES FROM THE ROOT OF A SPINAL NERVE.

At *a*, where they join the spinal cord, they are varicose; lower down at *b*, they are uniform and larger (from Valentin).

globules held together by a fine transparent thread. As already remarked, the double contour caused by congelation of the white substance does not appear in the highly-constricted parts. The axis takes no part in this change, indeed it may sometimes be seen running through the varicosities and undergoing no corresponding dilatation.

Neither in their course along the nervous cords, nor in the white part of the nervous centres, have these tubular fibres ever been observed to unite or anastomose together, nor are they seen to divide into branches ; it is therefore fair to conclude that, though bound up in numbers in the same nervous cords, they merely run side by side like the threads in a skein of silk, and that they maintain their individual distinctness throughout the trunk and branches of a nerve ; but in many cases the fibres divide in approaching the peripheral termination of the nerve, as will be again noticed.

Grey, Pale, Non-medullated, or *Gelatinous Fibres* (fig. LXXVI).—The white fibres, at the peripheral extremities of many nerves, lay aside their medullary sheath and dark borders, and are prolonged into pale fibres, often

Fig. LXXVI.

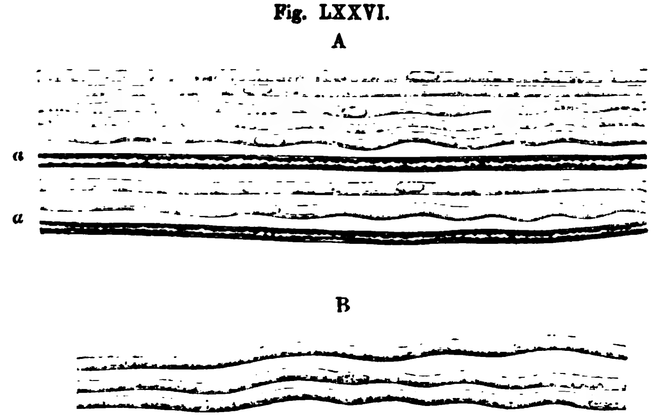


Fig. LXXVI.—Grey, Pale or Gelatinous Nerve-Fibres (from Max Schultze. Magnified between 400 and 500 diameters).

A. From a branch of the olfactory nerve of the sheep; at *a*, *a*, two dark bordered or white fibres, from the fifth pair, associated with the pale olfactory fibres.
B. From the sympathetic nerve.

minutely dividing, which seem to represent the axis-cylinder deprived of surrounding white substance, and either naked or covered with a prolongation of the primitive sheath. But, apart from these pale continuations of white fibres, there are nerve-fibres which exhibit the non-medullated character throughout their whole length. These are the pale, grey fibres first pointed out by Remak, and commonly designated by his name, which are found, with or without associated white fibres, chiefly in the sympathetic but also in other nerves. The branches of the olfactory nerve of man and mammalia consist wholly of these pale fibres. They were named gelatinous (by Henle) from their aspect, not their chemical nature. They measure from $\frac{1}{8000}$th to $\frac{1}{6000}$th of an inch in diameter, appear flattened, translucent, homogeneous, or very faintly granular, and sometimes finely striated longitudinally. At short distances they bear oblong nuclei, which have been supposed to belong to a sheath (Max. Schultze). As these fibres generally end peripherally—and some (olfactory) are known to begin centrally—by a

number of fine fibrils, it has been by some anatomists suggested, by others maintained, that they are really bundles of immeasureably fine filaments; moreover, it is asserted that the fibrillar structure may be actually observed in pale sympathetic fibres; but this view, however probable, stands in need of confirmation.

Pale fibres are also met with (in the sympathetic nerve especially) which appear as fine simple filaments with fusiform enlargements, often finely granular in substance, and possibly of the nature of nuclei, but placed in the continuity of the fibre, and not merely attached to a sheath.

Nerve-cells, sometimes called *Nerve-vesicles*.—These, as already mentioned, constitute the second kind of structural elements proper to the nervous system. They are found in the grey matter of the cerebro-spinal centre and ganglions, constituting a principal part of the last-mentioned bodies, and thence often named *ganglionic corpuscles* or *ganglion globules*; they exist also in some of the nerves of special sense at their peripheral expansions, and, here and there, in the course of certain other nerves. The nerve-cells may have a spheroidal, oval, or pyriform shape (fig. LXXVII); and such for the most part is their form in the ganglions; but many, and especially those from the grey matter of the spinal cord and brain, are of an angular or irregular figure, and send out processes,

Fig. LXXVII.

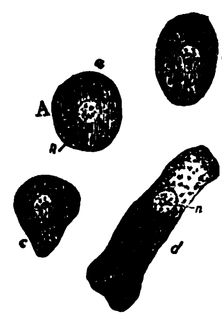


Fig. LXXVII. — Ganglionic Nerve-Cells, magnified (from Valentin).

Fig. LXXVIII.

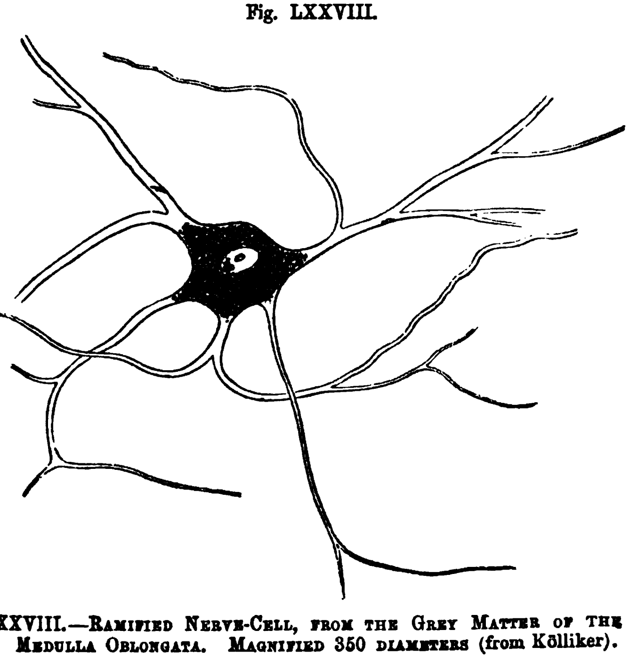


Fig. LXXVIII.—Ramified Nerve-Cell, from the Grey Matter of the Human Medulla Oblongata. Magnified 350 diameters (from Kölliker).

often finely branched, from their circumference (figs. LXXVIII and LXXIX); and then they are often named, according to the number of processes they present, uni-, bi-, and multipolar; terms obviously ill chosen, but rendered

Fig. LXXIX.

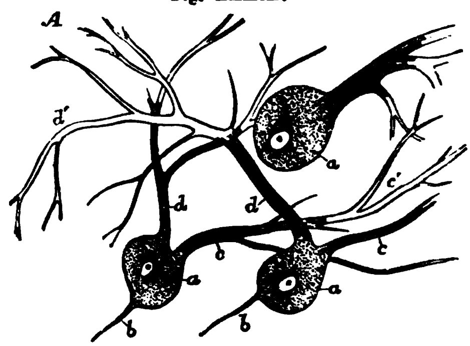


Fig. LXXIX.—NERVE-CELLS FROM THE CORTICAL GREY MATTER OF THE CEREBELLUM. MAGNIFIED 260 DIAMETERS (from Kölliker, reduced).

current by use. They have each, as a rule, a large, well-defined, clear, round nucleus, and within this an equally distinct nucleolus, or sometimes more than one. The substance of the cell is soft and translucent, but finely granular or punctuated, and slightly tinged throughout with a brownish red colour; and cells are often seen, especially those of the large ramified kind, with one, or sometimes two, much deeper coloured brown patches, caused by groups of pigment granules; the colour is deeper in adult age than in infancy.

The bodies in question, although they still are commonly called "cells," appear to be destitute of a proper cell-wall. In the ganglia, it is true, they are enclosed in a distinct capsule; but this is probably adventitious, and pertaining to the connective structure in which they are lodged. The outrunners or branches are formed by prolongations of the same soft substance which forms the cell body; they are, therefore, very readily broken, and the cells thereby mutilated, in the manipulation required for their insulation.

Various recent observers describe a faint striation, or a very fine fibrillation, in the branched cells; the lines or fibrils are said to run along the outrunners, and also to pass continuously through the body of the cell from one branch to another; it is further alleged by one writer (Frommann), that bundles of filaments proceed from the nucleus and pass out of the cell at various points, in each of which bundles there is one fibril connected with the nucleolus.

Other nerve-cells (fig. LXXX, *a*) are found in the nervous substance, which are distinguished chiefly by the pellucid, colourless, and homogeneous aspect of the matter contained in them; such cells possess a nucleus like the rest; they are seldom large, and have usually a simple round or oval figure. They occur along with nerve-cells of the kind before described. Lastly, small bodies of the size of human blood-corpuscles and upwards, containing one or more bright specks like nucleoli, abound in the grey matter in certain situations (fig. LXXX, *b*, *c*). These bodies, which are sometimes called "granules" (*Körner* in German), resemble the nuclei of nerve-cells; and it may be a question whether they are not the nuclei of cells in which the

cell-matter or protoplasm is very scanty, and accidentally detached in examination. These nucleus-like bodies are very abundant in the superficial grey matter of the cerebellum.

Fig. LXXX.

Fig. LXXX.—SMALL NERVE-CELLS.

a, from the (cortical) grey matter of the brain. *b* and *c* are from the cortical substance of the cerebellum; *b* resemble detached cell-nuclei. *c* are smaller bodies, also like cell-nuclei, densely aggregated (from Hannover, magnified 340 diameters).

In the grey matter of the cerebro-spinal centre, the nerve-cells appear as if imbedded in a sort of matrix of granular substance, interposed between them in greater or less quantity, and very generally traversed by nerve-fibres. But it is very probable that the appearance of granular or molecular matter results from a confused interlacement of very fine fibrils, and especially of the fine ramifications of nerve-cells; or from the crushing and breaking down of such fibres in the process of examination. In the ganglia properly so called, the cells are packed up among nerve-fibres, but each cell is also immediately surrounded by an inclosing capsule (fig. LXXXII. and LXXXIII.).

The proper nervous substance of the brain and spinal cord is described by Kölliker as being traversed in all directions and supported by a framework of connective tissue—the "retiform" connective tissue described at page lxxix. This is formed of an interunion of ramified connective-tissue corpuscles, or of a network of fine fibres alone, originally proceeding from such corpuscles. Kölliker names this supporting structure the *reticulum* of the nervous centres (fig. LXXXI.). Virchow proposes the term *neuroglia*. It is not merely an open mesh-work, but consists also of fine laminæ formed of a close interlacement of the finest fibrils, disposed as membranous partitions and tubular compartments for separating and inclosing the nervous bundles.

Fig. LXXXI.

Fig. LXXXI.—PART OF THE RETICULUM FROM THE SPINAL CORD.

Open meshes are seen generally, but at two places the close lamelliform interlacements are shown. Magnified 350 diameters (from Kölliker).

Such being the structural elements of the nervous substance, we have next to consider the arrangement of these cells and fibres in the ganglia and nerves which they contribute to form; the intimate structure of the encephalon and spinal cord being treated of in the part of this work which is devoted to special or descriptive anatomy.

OF THE GANGLIA.

The bodies so named are found in the following situations—viz.: 1. On the posterior root of each of the spinal nerves, on one, and probably the corresponding root of the fifth nerve of the encephalon, and on the seventh pair, glosso-pharyngeal and pneumogastric nerves, involving a greater or less amount of their fibres; also on the branches of certain cerebro-spinal nerves. 2. Belonging to the sympathetic nerve. (*a*)—In a series along each side of the vertebral column, connected by nervous cords, and constituting what was once considered as the trunk of the sympathetic. (*b*)—On branches of the sympathetic; occurring numerously in the abdomen, thorax, neck, and head; generally in the midst of plexuses, or at the point

of union of two or more branches. Those which are found in several of the fossæ of the cranium and face are for the most part placed at the junction of fine branches of the sympathetic with branches, usually larger, of the cerebro-spinal nerves; but they are generally reckoned as belonging to the sympathetic system.

The ganglia differ widely from each other in figure and size: those which have been longest known to anatomists are most of them large and conspicuous objects; but, by the researches of Remak and others, it has been shown that there are numerous small, or what might be almost termed microscopic ganglia, disposed along the branches of nerves distributed to the tongue, the heart, the lungs, and some other viscera; also connected with fine plexuses of nerves between the coats of the intestines.

Ganglions are invested externally with a thin but firm and closely adherent envelope, continuous with the fibrous sheath of the nerves, and composed of connective tissue; this outward covering sends processes inwards through the interior mass, dividing it, as it were, into lobules, and supporting the numerous fine vessels which pervade it. A section carried through a ganglion, in the direction of the nervous cords connected with it, discloses to the naked eye merely a collection of reddish-grey matter traversed by the white fibres of the nerves. The nervous cords on entering lay aside their investing sheath and spread out into smaller bundles, between which the grey ganglionic substance is interposed; and their fibres are gathered up again into cords, furnished with sheaths, on issuing from the ganglion. The microscope shows that this grey substance consists of nerve-cells and fibres with supporting connective tissue. The nerve-cells, or ganglion globules, have mostly a round, oval, or pyriform figure (figs. LXXVII., LXXXII. and LXXXIII.). They are inclosed in capsules formed of a transparent membrane with attached or imbedded nuclei.

Of the relation between the nerve fibres in a ganglion and the ganglion cells, it may be stated that many fibres pass through without being connected with the cells, but that every nerve-cell is connected with a fibre or with fibres. According to Dr. Beale, each cell is connected with, at least, two fibres, which, on reaching the nervous bundle in which they are distributed, run in opposite directions (fig. LXXXII). One of the fibres is straight, usually of tolerable size, and connected with the cell at one spot like a stalk—in pyriform cells at the small end. The other, usually smaller, begins or is attached at some distance from the insertion of the first, and makes several turns on the surface of the cell, but within its capsule, which are continued as spiral coils round the straight fibre, and then the two part company and, apparently, run in opposite directions in the nervous bundle in which they mingle.

The spiral fibre bears large oblong nuclei along its course. These are seen on its spiral turns upon the surface of the cell, and some, at the commencement of the fibre, seem to be beneath the surface. It may be single from the first, or begin by two or more filaments which join at some distance from the cell. Both fibres increase in size as they proceed. They have at first the character of pale fibres (or axis cylinders), then one of them—generally the straight one, but it may be the other—at a short distance from the cell acquires a medullary sheath and becomes a dark bordered fibre. At the same time it cannot be positively said that both fibres may not become dark bordered, or both continue as pale fibres. The spiral fibre may make more or fewer coils, and Dr. Beale thinks they are more numerous in older cells—for in some cases the smaller fibre (answering to the spiral one elsewhere) is not coiled; and the cells in such cases he considers to be young or recently formed.

Dr. Beale's observations have been made chiefly on the ganglia of frogs, the cells of which have very commonly a pyriform shape like the one represented in the figure. In mammalia they are more spheroidal, and the observation of their connection with fibres is more difficult; but from examinations in mammalia, so far as they have gone, Dr. Beale infers that the relation of the cells and fibres is essentially the same as in frogs.

Fig. LXXXII.

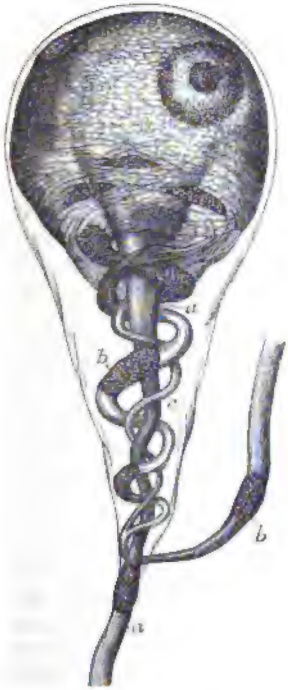


Fig. LXXXIII.

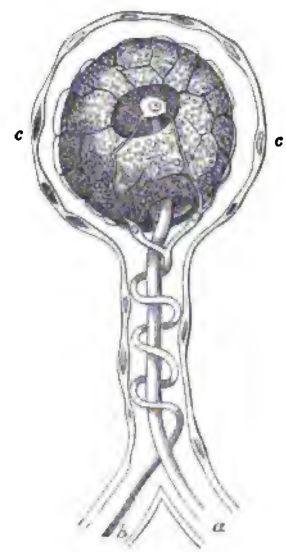


Fig. LXXXII.—Ganglion-Cell of a Frog, magnified; according to Beale.

Reduced and adapted from one of his figures. *a*, *a*, straight fibre; *b*, *b*, coiled fibre; *c*, smaller one joining it.

Fig. LXXXIII.—Magnified Ganglion-Cell, from the Sympathetic of the Frog, according to J. Arnold. Virch. Arch. 1865.

a, straight fibre; *b*, coiled fibre, arising by a superficial net connected with nucleolus of the cell; *c*, *c*, capsule with nuclei.

Two subsequent writers, Julius Arnold and L. G. Courvoisier, have confirmed Dr. Beale's original observation in almost every point; but whilst Beale describes the two fibres as connected with the substance of the cell and at its surface only—or, at least, could not obtain satisfactory evidence of its passing into the interior—Arnold, and (after him) Courvoisier describe (as had previously been done by Harless and others) the straight fibre as traceable into the nucleus, with which Arnold thinks its medullary sheath, here altogether inconsiderable, is continuous, whilst the axial part ends in the nucleolus, which he regards as the knobbed end of the axis cylinder. Then both describe a network of exquisitely fine fibrils, which, springing from the nucleolus as a centre, traverses the substance of the cell and comes to the surface between the cell-body and its sheath, and finally unites into the spiral fibre. According to this account, the nucleolus is, as it were, the end of the straight fibre and beginning of the spiral one, or *vice versâ;* or, at least, the point of organic connection between them in the cell.

Courvoisier describes both fibres as acquiring a medullary sheath, the straight one first. He has found the above described structure in the ganglia of fish, birds, and mammals; but whilst in the frog the cell has never, or scarcely ever, more than one straight and very rarely more than one spiral fibre, he finds that in other vertebrates a cell may give off such twin fibres from two or more parts of its circumference.

In the spinal ganglia of the skate, torpedo, and dog-fish, there is a different arrangement. In these, as first pointed out by R. Wagner, two fibres are connected with each ganglion-cell, at opposite sides or opposite poles,—one directed centrally toward the root of the nerve, and the other outwardly towards its branches.

CEREBRO-SPINAL NERVES.

These are formed of the nerve-fibres already described, collected together and bound up in sheaths of connective tissue. A larger or smaller number of fibres inclosed in a tubular sheath form a slender round cord of no determinate size, usually named a *funiculus*; if a nerve be very small it may consist of but one such cord, but in larger nerves several funiculi are united together into one or more bundles, which, being wrapped up in a common membranous covering constitute the nerve (fig. LXXXIV.). Accordingly, in dissecting a nerve, we first come to an outward covering, formed of connective tissue, often so strong and dense that it might well be called fibrous. From this common sheath we trace laminæ passing inwards between the larger and smaller bundles of funiculi, and finally between the funiculi themselves, connecting them together as well as conducting and supporting the fine blood-vessels which are distributed to the nerve. But, besides the interposed areolar tissue which connects these smallest cords, each funiculus has a special sheath of its own, as will be further noticed presently.

Fig. LXXXIV.

Fig. LXXXIV.—Portion of the Trunk of a Nerve, consisting of many smaller Cords or Funiculi wrapped up in a common Sheath.

A, the nerve; B, a single funiculus drawn out from the rest (from Sir C. Bell).

The common sheath and its subdivisions consist of connective tissue, presenting the usual white and yellow constituent fibres of that texture, the latter being present in considerable proportion. The special sheaths of the funiculi, on the other hand, appear to be formed essentially of a fine transparent membrane, which may without difficulty be stripped off in form of a tube from the little bundle of nerve-fibres of which the funiculus consists. When examined with a high power of the microscope, this membrane presents the aspect of a thin transparent film, which in some parts appears to be quite simple and homogeneous, but is more generally marked with extremely fine reticulated fibres. Corpuscles resembling elongated cell-nuclei may also be seen upon it when acetic acid is applied. The tissue investing a nerve and inclosing its proper fibres, as now described, is named the *neurilemma*, and the term is for the most part applied indiscriminately to the whole of the enveloping structure, though some anatomists use it to denote only the sheaths of the funiculi and smaller fasciculi, whilst they name the general external covering of the nerve its "cellular sheath" (*vagina cellulosa*).

Some recent writers, believing that the primitive sheath or membranous tube of the nerve-fibre corresponds to the sarcolemma of muscle, have proposed to designate it as the neurilemma, and to use the term *perineurium* for the coarser sheathing of the nerves and nervous cords, to which the term

neurilemma has been heretofore applied. The use of the term *perineurium* is unobjectionable and may sometimes be convenient, but the proposed new and restricted application of the term *neurilemma* will, I think, lead to ambiguity, and is of doubtful propriety.

The funiculi of a nerve are not all of one size, but all are sufficiently large to be readily seen with the naked eye, and easily dissected out from each other. In a nerve so dissected into its component funiculi, it is seen that these do not run along the nerve as parallel insulated cords, but join together obliquely at short distances as they proceed in their course, the cords resulting from such union dividing in their further progress to form junctions again with collateral cords; so that in fact the funiculi composing a single nervous trunk have an arrangement with respect to each other similar to that which we shall presently find to hold in a plexus formed by the branches of different nerves. It must be distinctly understood, however, that in these communications the proper nerve-fibres do not join together or coalesce. They pass off from one nervous cord to enter another, with whose fibres they become intermixed, and part of them thus intermixed may again pass off to a third funiculus, or go through a series of funiculi and undergo still further intermixture; but throughout all these successive associations (until near the termination of the nerve) the fibres remain, as far as known, individually distinct, like the threads in a rope.

The fibres of the cerebro-spinal nerves are chiefly, in some cases perhaps exclusively, of the white or medullated kind, but in most instances there are also grey fibres in greater or less number. Moreover, it has often appeared to me as if there were filaments of extreme tenuity, like the white filaments of connective tissue, but of doubtful nature, mixed up with well-characterised nerve-fibres within the sheaths of the funiculi. Lying alongside each other, the fibres of a funiculus form a little skein or bundle, which runs in a waving or serpentine manner within its sheath; and the alternate lights and shadows caused by the successive bendings being seen through the sheath, give rise to the appearance of alternate light and dark cross stripes on the funiculi, or even on larger cords consisting of several funiculi. On stretching the nerve, the fibres are straightened and the striped appearance is lost.

Vessels.—The blood-vessels of a nerve supported by the sheath divide into very fine capillaries, said by Henle to measure in the empty state not more than $\frac{1}{4000}$th of an inch in diameter. These, which are numerous, run parallel with the fibres, many of them within the funicular sheaths, but are connected at intervals by short transverse branches, so as in fact to form a network with long narrow meshes.

Branching and conjunction of Nerves.—Nerves in their progress very commonly divide into branches, and the branches of different nerves not unfrequently join with each other. As regards the arrangement of the fibres in these cases, it is to be observed, that, in the branching of a nerve, collections of its fibres successively leave the trunk and form branches; and that, when different nerves or their branches intercommunicate, fibres pass from one nerve to become associated with those of the other in their further progress; but in neither case (unless towards their peripheral terminations) is there any such thing as a division or splitting of an elementary nerve-fibre into two, or an actual junction or coalescence of two such fibres together.

A communication between two nerves is sometimes effected by one or two connecting branches. In such comparatively simple modes of connec-

tion, which are not unusual, both nerves commonly give and receive fibres; so that, after the junction, each contains a mixture of fibres derived from two originally distinct sources. More rarely the fibres pass only from one of the nerves to the other, and the contribution is not reciprocal. In the former case the communicating branch or branches will of course contain fibres of both nerves, in the latter of one only.

In other cases the branches of a nerve, or branches derived from two or from several different nerves, are connected in a more complicated manner, and form what is termed a plexus. In plexuses—of which the one named "brachial" or "axillary," formed by the great nerves of the arm, and the "lumbar" and "sacral," formed by those of the lower limb and pelvis, are appropriate examples—the nerves or their branches join and divide again and again, interchanging and intermixing their fibres so thoroughly, that, by the time a branch leaves the plexus, it may contain fibres from all the nerves entering the plexus. Still, as in the more simple communications already spoken of, the fibres, so far as is known, remain individually distinct throughout.

Some farther circumstances remain to be noticed as to the course of the fibres in nerves and nervous plexuses.

Gerber has described and figured nerve-fibres, which, after running a certain way in a nerve, apparently join in form of loops with neighbouring fibres of the same bundle, and proceed no further. Such loops might of course be represented as formed by fibres which bend back and return to the nervous centre; and so Gerber considers them. He regards them as looped terminations of sentient fibres appropriated to the nerve itself—as the *nervi nervorum*, in short, on which depends the sensibility of the nerve to impressions, painful or otherwise, applied to it elsewhere than at its extremities. The whole matter is, however, involved in doubt: for, admitting the existence of the loops referred to, which yet requires confirmation, it is not impossible that they may be produced by fibres which run back only a certain way, and then, entering another bundle, proceed onwards to the termination of the nerve. Again, it has been supposed, that, in some instances, of nervous conjunctions, certain collections of fibres, after passing from one nerve to another, take a retrograde course in that second nerve, and, in place of being distributed peripherally with its branches, turn back to its root and rejoin the cerebro-spinal centre. An apparent example of such nervous arches without peripheral distribution is afforded by the optic nerves, in which various anatomists admit the existence of arched fibres that seem to pass across the commissure between these nerves from one optic tract to the other, and to return again to the brain. These, however, are perhaps to be compared with the commissural fibres of the brain itself, of which there is a great system connecting the symmetrical halves of that organ. But instances of a similar kind occurring in other nerves have been pointed out by Volkmann; as in the connection between the second and third cervical nerves of the cat, also in that of the fourth cranial nerve with the first branch of the fifth in other quadrupeds, and in the communications of the cervical nerves with the spinal accessory and the descendens noni. But certain fibres of the optic nerves take a course deviating still more from that followed generally, for they appear to be continued across the commissure from the eyeball and optic nerve of one side to the opposite nerve and eye, without being connected with the brain at all, and thus to form arches with peripheral terminations, but no central connection. In looking, however, for an explanation of this arrangement, it must be borne in mind that the retina contains nerve-cells, like those of the nervous centres, and perhaps the fibres referred to may be intended merely to bring the collections of nerve-cells of the two sides into relation independently of the brain. Julius Arnold has found an arrangement of fibres at the junctions of the nerve-plexus of the iris similar to that in the optic commissure.*

The disposition of the fibres at the points of division and junction of the branches

* Virchow's Archiv. 1863.

of nerves still requires further investigation. For some interesting observations on the subject the reader is referred to a paper by Dr. Beale.*

Origins or Roots of the Nerves.—The cerebro-spinal nerves, as already said, are connected by one extremity to the brain or to the spinal cord, and this central extremity of a nerve is, in the language of anatomy, named its origin or root. In some cases the root is single, that is, the funiculi or fibres by which the nerve arises are all attached at one spot or along one line or tract; in other nerves, on the contrary, they form two or more separate collections, which arise apart from each other and are connected with different parts of the nervous centre, and such nerves are accordingly said to have two or more origins or roots. In the latter case, moreover, the different roots of a nerve may differ not only in their anatomical characters and connections, but also in function, as is well exemplified in the spinal nerves, each of which arises by two roots, an anterior and a posterior—the former containing the motory fibres of the nerve, the latter the sensory.

The fibres of a nerve, or at least a considerable share of them, may be traced to some depth in the substance of the brain or spinal cord, and hence the term "apparent or superficial origin" has been employed to denote the place where the root of a nerve is attached to the surface, in order to distinguish it from the "real or deep origin" which is beneath the surface and concealed from view.

To trace the different nerves back to their real origin, and to determine the points where, and the modes in which their fibres are connected with the nervous centre, is a matter of great difficulty and uncertainty; and, accordingly, the statements of anatomists respecting the origin of particular nerves are in many cases conflicting and unsatisfactory. Confining ourselves here to what applies to the nerves generally, it may be stated, that their roots, or part of their roots, can usually be followed for some way beneath the surface, in form of white tracts or bands distinguishable from the surrounding substance; and very generally these tracts of origin may be traced towards deposits of grey nervous matter situated in the neighbourhood; such, for instance, as the central grey matter of the spinal cord, the grey centres of the pneumo-gastric and glosso-pharyngeal nerves, the corpora geniculata and other larger grey masses connected with the origin of the optic nerve. It would further seem probable that certain fibres of the nerve roots take their origin in these local deposits of grey matter, whilst others become continuous with the white fibres of the spinal cord or encephalon, which are themselves connected with the larger and more general collections of grey matter situated in the interior or on the surface of the cerebro-spinal centre.

There is still much uncertainty as to the precise mode in which the nerve-fibres originating or terminating in the grey matter are related to its elements, and for the most part, indeed, individual fibres on being traced into the grey matter, become so hidden in the mass as to elude further scrutiny. Nevertheless, as a continuity between the nerve-fibres and nerve-cells in the grey matter has now been traced in individual examples by many different observers, and as such connections may be held to be general in the ganglions, it is not unfair to infer that, but for the obstacles to successful investigation, the cells in the grey matter of the cerebro-spinal centre would by this time also have been shown to be generally connected with the nerve-fibres.

* On the Branching of Nerve Trunks, &c., Archives of Medicine, vol. iv. p. 127.

Three modes of connection of cells with fibres are described. 1. From a cell which may have several branched outrunners, one stout unbranched process is continued into a nerve-fibre, at first naked, and probably representing only the axis cylinder, then acquiring a medullary sheath and dark borders, and finally a membranous tube or primitive sheath. 2. From one or more finely divided branches of a cell, or of more than one cell, equally fine fibrils are prolonged, which coalesce into a pale fibre, having the characters of an axis cylinder, which then, as in the former case, may in its progress become a dark-bordered medullated fibre. 3. The extreme ramifications of a cell or cells become connected, as in the last case, with fibrils, which join into a nerve-fibre; but the connection takes place by the intervention of small bipolar cells, which are by one pole continuous with the branches of the larger cell or cells, and by the other with fine fibrils which join into a pale fibre, or into an axis cylinder of a dark bordered fibre. Gerlach, and after him Waldeyer and others, have described this last mode of connection, as seen by them in the cerebellum. In the cortical grey matter of the cerebellum there are well known large cells generally with one undivided process directed centrally, and two or three finely divided branches towards the surface (fig. LXXIX.). Scattered in the neighbourhood of these large cells, and also collected in a layer named the *stratum ferrugineum*, or rust-coloured layer, are numerous small cells, often called granules (fig. LXXX. *c*); and it is alleged by the above named authorities that fine ramifications of the large cells join neighbouring small cells or pass inwards to join those of the stratum ferrugineum, and that the small or intermediate cells are, on the other hand, connected with filaments which coalesce into nerve-fibres as above described. This statement derives support from the important observations of Mr. Lockhart Clarke, on the structure of the olfactory bulb. Along with this indirect connection through small intervening cells, Gerlach supposes that a process or processes of the large cells pass directly into nerve-fibres; and should such direct connection take place by the prolongation of an unbranched cell-process into a nerve-fibre, the arrangement would be analogous to that in the ganglia; the simple origin. representing that of the straight fibre from the ganglion-cell, whilst the ramified origin, with the intervening small cells, might be compared to that of the superficial or spiral fibre, with its interposed nuclei.

The fibres of origin of a nerve, whether deeply implanted or not, on quitting the surface of the brain or spinal cord to form the apparent origin or free part of the root, are in most cases collected into funiculi, which are each invested with a sheath of neurilemma. This investment is generally regarded as a prolongation of the pia mater, and in fact its continuity with that membrane may be seen very plainly at the roots of several of the nerves, especially those of the cervical and dorsal nerves within the vertebral canal, for in that situation the neurilemma, like the pia mater itself, is much stronger than in the cranium. The funiculi, approaching each other if originally scattered, advance towards the foramen of the skull or spine which gives issue to the nerve, and pass through the dura mater, either in one bundle and by a single aperture, or in two or more fasciculi, for which there are two or more openings in the membrane. The nerve roots in their course run beneath the arachnoid membrane, and do not perforate it on issuing from the cranio-vertebral cavity; for the loose or visceral layer of the arachnoid is prolonged on the nerve and loosely surrounds it as far as the aperture of egress in the dura mater, where, quitting the nerve, it is reflected upon the inner surface of the latter membrane, and becomes continuous with the parietal or adherent layer of the arachnoid. The nerve, on escaping from the skull or spine, acquires its external, stout, fibrous sheath, which connects all its funiculi into a firm cord, and then, too, the nerve appears much thicker than before its exit. The dura mater accompanies the nerves through the bony foramina, and becomes continuous with their external sheath and (at the cranial foramina) with the pericranium;

but the sheath does not long retain the densely fibrous character of the membrane with which it is thus connected at its commencement.

The arrangement of the membranes on the roots of certain of the cranial nerves requires to be specially noticed.

The numerous fasciculi of the olfactory nerve pass through their foramina almost immediately after springing from the olfactory bulb, and then also receive their neurilemma. The bulb itself, and intracranial part of the nerve, which are to be regarded as being really a prolongation or lobe of the brain, are invested externally by the pia mater, but are not fasciculated. The arachnoid membrane passes over the furrow of the brain in which this part of the nerve lies, without affording it a special investment.

The optic nerve becomes subdivided internally into longitudinal fasciculi by neurilemma a little way in front of the commissure: on passing through the optic foramen it receives a sheath of dura mater, which accompanies it as far as the eyeball. The acoustic nerve becomes fasciculated, receives its neurilemma, and acquires a firm structure on entering the meatus auditorus internus in the temporal bone, towards the bottom of which it presents one or more small ganglionic swellings containing the characteristic cells. Up to this point it is destitute of neurilemma, and of soft consistence, whence the name "portio mollis" applied to it.

The larger root of the fifth pair acquires its neurilemma and its fasciculated character sooner at its circumference than in the centre, so that, in the round bunch of cords of which it consists, those placed more outwardly are longer than those within, and, when all are pulled away, the non-fascicular part of the nerve remains in form of a small conical eminence of comparatively soft nervous substance.

Most of the nerves have ganglia connected with their roots. Thus, the spinal nerves have each a ganglion on the posterior of the two roots by which they arise; and in like manner several of the cranial, viz., the fifth, seventh, glosso-pharyngeal, and pneumo-gastric, are furnished at their roots, or at least within a short distance of their origin, with ganglia which involve a greater or less number of their fibres, as described elsewhere in the special anatomy of those nerves.

Termination, or peripheral distribution, of nerves.—It may be stated, generally, and apart from what may apply to special modes of termination, that, in approaching their final distribution, the *fibres* of nerves, medullated and non-medullated, commonly divide into branches (fig. LXXXV); and the former, either before or after division, generally lose their medullary sheath, and consequently their dark borders, and take on the characters of pale fibres. The axis-cylinder participates in the division, and it might be said that the white fibres are represented in their further progress, by the axis-cylinder and its ramifications; still, the primitive sheath or membranous tube continues some way along these pale branches after the medullary sheath has ceased, but may finally too desert them. By repeated division the fibres become smaller and smaller; but whilst some of the resulting small fibres may be simple, many are really bundles of exquisitely fine pale fibrils, straight, sinuous, or somewhat tortuous in their course. They bear nuclei, some of which, no doubt, may appertain to the prolongation of the primitive sheath; but others, generally fusiform and granular, are interposed, as it were, in the course of the fibres, and are continuous with them at either end; nuclei, moreover, of a triangular or irregular shape, are common at the bifurcations of the fibres. These pale fibres often join into networks; but their further disposition in different parts will be treated of below. In the meantime it must be explained that the original dark-bordered fibres which thus undergo division and change, or which may proceed singly to end in a different and special manner, are commonly provided with a tolerably strong sheath with nuclei, which, as it stands well apart from

the dark borders of the fibre, is very conspicuous. This is sometimes considered to be only the primitive sheath of the fibre modified in character,

Fig. LXXXV.

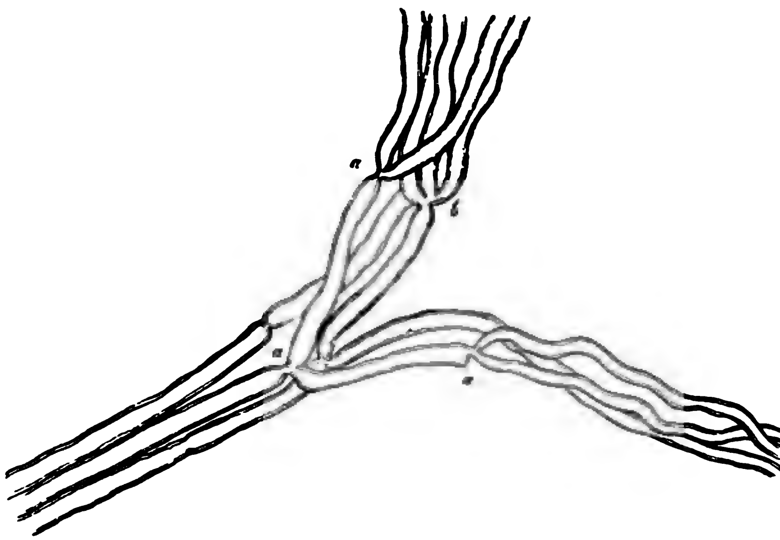


Fig. LXXXV.—Small Branch of a Muscular Nerve of the Frog, near its termination, showing divisions of the Fibres.

a, into two; *b*, into three; magnified 350 diameters.—(From Kölliker.)

but it seems more probable that it is derived from the neurilemma or perineurium which incloses the fine bundles or funiculi, and, as these part into smaller collections and single fibres, undergoes a corresponding division, and finally sends sheaths along single fibres.

In further treating of the terminations of nerves it will be convenient to consider the sensory and motor nerves separately.

Of the *sensory*, or, at least, *non-muscular* nerves, the following modes of final distribution have been recognised.

A. By *networks*, or *terminal plexuses*. These are formed by the branching and interjunction of the pale fibres above described. The meshes of the net may be at first wider, and the threads, or bundles of threads, larger, but from these, finer filaments forming closer reticulations proceed, and then sometimes the nuclei become less frequent, or disappear. Such networks are found in the skin of the frog, rat, and mouse; in various parts of the mucous membranes, in the cornea, and also in the connective tissue beneath serous membranes or between their layers in different parts —of which the mesentery of the frog affords a good example. In some of these cases the nerve-fibres come into the vicinity of connective-tissue-corpuscles, but, so far as I have been able to see, are not connected with them.

B. *Sensory terminal organs*. Three varieties of these are now recognised, viz., *a., end-bulbs—b., touch-corpuscles*, and *c., Pacinian bodies*. These have so far a common structure, that in all of them there is an inward part or *core* (*Innenkolben* Germ.) of soft, translucent, finely granular matter; an outer capsule of ordinary connective tissue with its pertaining corpuscles; and, finally, one or sometimes more nerve-fibres, pale and without dark contours, which pass into the core and apparently end with a free, usually somewhat swollen, or knobbed extremity. Thus agreeing in their internal and probably essential structure, the terminal organs differ chiefly, or at least most obviously, in their capsule, which, simple in the end-bulbs, becomes

highly complicated in the Pacinian bodies; and therefore in the further account of them it will be convenient to begin with the former, although the Pacinian bodies have been much longer known.

a. End-bulbs. Noticed incidentally by Kölliker, but first investigated and recognised as distinct organs by W. Krause, who named them *Endkolben*. Their figure in man and apes is usually spheroidal (fig. LXXXVI), but oblong in some quadrupeds. They measure about $\frac{1}{600}$th of an inch in diameter, but may exceed this in length with a less breadth, when of an oval shape. They have a simple outer capsule of connective tissue, bearing nuclei, and within this a core of clear soft matter, in which specks resembling fat-granules become visible after exposure to a solution of soda. To an end-bulb there proceeds usually one, but sometimes two, or even three dark-bordered nerve-fibres; and sometimes an originally single fibre divides into two or three immediately before entering the corpuscle; or several branches of one fibre may each run into a separate end-bulb. The fibre or fibres pass into the core, lose their dark borders, and appear to end, when their ends can be traced, in a bulbous extremity or knob. The nerve-fibre, when about to enter the corpuscle, is often much coiled, and this may be the case too with its pale continuation within, which contributes greatly to obscure its actual termination. End-bulbs have been hitherto found in the conjunctiva over the sclerotic coat of the eye, and in the mucous membrane on the floor of the mouth, the lips, soft palate, and tongue, being in these last-mentioned situations lodged in papillæ, or at their roots; also, more deeply, in the skin of the glans of the penis and clitoris.*

Fig. LXXXVI.

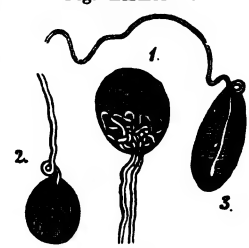


Fig. LXXXVI. — THREE NERVE-END-BULBS FROM THE HUMAN CONJUNCTIVA, TREATED WITH ACETIC ACID, MAGNIFIED 300 DIAMETERS.

1. With two nerve-fibres forming coils within. 2. With one nerve-fibre and fat-granules in the core. 3. Of an oval figure; termination of nerve distinct. Nuclei on the capsules of 1 and 2.—(From Kölliker, after a drawing by Lüdden).

Fig. LXXXVII.

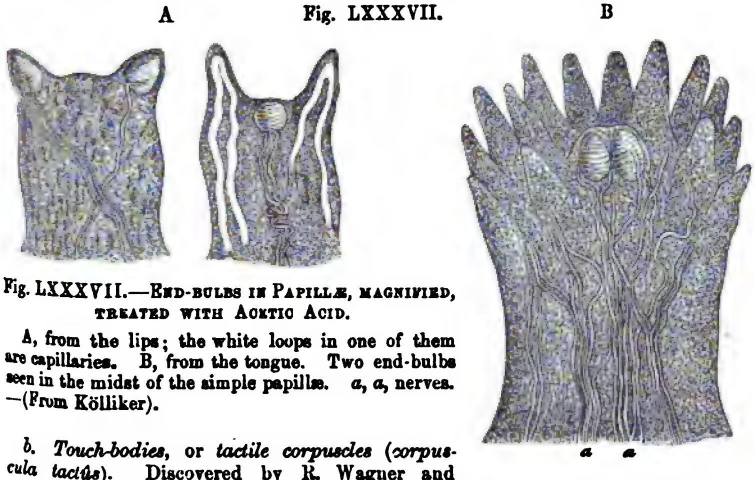


Fig. LXXXVII.—END-BULBS IN PAPILLÆ, MAGNIFIED, TREATED WITH ACETIC ACID.

A, from the lips; the white loops in one of them are capillaries. B, from the tongue. Two end-bulbs seen in the midst of the simple papillæ. *a*, *a*, nerves. —(From Kölliker).

b. Touch-bodies, or *tactile corpuscles* (*corpuscula tactûs*). Discovered by R. Wagner and Meissner. These are mostly of an oval shape, nearly $\frac{1}{300}$ of an inch long, and

* W. Krause has lately described peculiar organs in the skin of the penis and clitoris, allied to the end-bulbs, which he proposes to call *genital nerve-corpuscles*. They are various in form, but present a mulberry-like surface. One, or two, rarely three or four, dark-bordered nerve-fibres enter each of them. They have a delicate sheath of connective tissue, with many nuclei, and soft finely granular contents allied to the core of the end-bulbs.

$\frac{1}{300}$ of an inch thick. Within is a core of soft, transparent, homogeneous substance, with sparsely imbedded granules; outside, a capsule of connective tissue, with oblong nuclei directed transversely to the axis (and rendered more conspicuous by acetic acid or coloration with carmine), which, together perhaps with some horizontally wound fibres, give the corpuscle somewhat the appearance of a miniature fir-cone. One, two, or even more nerve-fibres, run to the corpuscle, and proceeding straight, or with serpentine windings, approach the summit, up to this point retaining their dark borders; they then pass into the core, and, so far as can be seen, end as fine pale fibres. The touch-corpuscles are found in the skin of the hand and foot, and one or two other parts, where they are inclosed in certain of the cutaneous papillæ, which usually include no vessels. It may be here observed that loops of nerves are sometimes seen in papillæ without touch-bodies, but probably they belong to a nerve on its way to end in the corpuscle of a neighbouring papilla.

Fig. LXXXVIII.

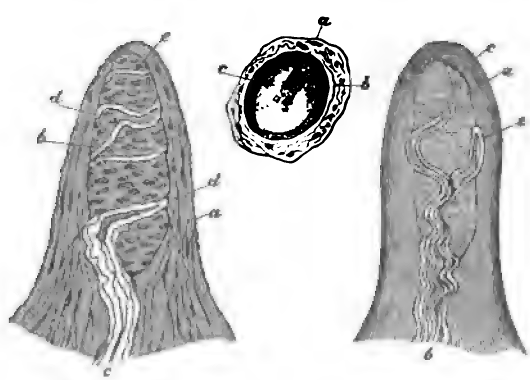


Fig. LXXXVIII.—Papillæ from the Skin of the Hand, freed from the Cuticle and exhibiting the Tactile Corpuscles. Magnified 350 diameters.

A. Simple papilla with four nerve-fibres. *a*, Tactile corpuscle; *b*, nerves. B. Papilla treated with acetic acid; *a*, cortical layer with cells and fine elastic filaments; *b*, tactile corpuscle with transverse nuclei; *c*, entering nerve with neurilemma or perineurium; *d*, nerve-fibres winding round the corpuscle. C. Papilla viewed from above so as to appear as a cross section. *a*, cortical layer; *b*, nerve-fibre; *c*, sheath of the tactile corpuscle containing nuclei; *d*, core (after Kölliker).

c. Pacinian bodies. In dissecting the nerves of the hand and foot, certain small oval bodies like little seeds, are found attached to their branches as they pass through the subcutaneous fat on their way to the skin; and it has been ascertained that each of these bodies receives a nervous fibre which terminates within it. The objects referred to were more than a century ago described and figured by Vater,* as attached to the digital nerves, but he did not examine into their structure, and his account of them seems not to have attracted much notice. Within the last few years, their existence has been again pointed out by Cruveilhier and other French anatomists, as well as by Professor Pacini of Pisa, who appears to be the first writer that has given an account of the internal structure of these curious bodies, and clearly demonstrated their essential connection with the nervous fibres. The researches of Pacini have been followed up by Henle and Kölliker,† who named the corpuscles after the Italian savant; and to their memoir, as well as to the article "Pacinian Bodies," by Mr. Bowman, in the "Cyclopædia of Anatomy," and to more recent

* Abr. Vater, Diss. de Consensu Partium Corp. hum.; Vitemb. 1741, (recus. in Halleri Disp. Anat. Select. tom. ii.) Ejusd. Museum Anatomicum; Helmst. 1750.

† Ueber die Pacinischen Körperchen; Zurich, 1844.

papers by W. Krause * and Engelmann,† the reader is referred for details that cannot be conveniently introduced here.

The little bodies in question (fig. LXXXIX) are, as already said, attached in great numbers to the branches of the nerves of the hand and foot, and here and there one or two are found on other cutaneous nerves. They have been discovered also within the abdomen on the nerves of the solar plexus, and they are nowhere more distinctly seen or more conveniently obtained for examination, than in the mesentery and omentum of the cat, between the layers of which they exist abundantly. They have been found on the pudic nerves on the glans penis and bulb of the urethra, on the intercostal nerves, sacral plexus, cutaneous nerves of the upper arm and neck, and on the infraorbital nerve. Lately they have been recognised on the periosteal nerves, and, in considerable numbers, on the nerves of the joints. They are found in the fœtus, and in individuals of all ages. The figure of these corpuscles is oval, somewhat like that of a grain of wheat,—regularly oval in the cat, but mostly curved or reniform in man, and sometimes a good deal distorted. Their mean size in the adult is from $\frac{1}{15}$ to $\frac{1}{10}$ of an inch long, and from $\frac{1}{25}$ to $\frac{1}{20}$ of an inch broad. They have a whitish, opaline aspect: in the cat's mesentery they are usually more transparent, and then a white line may be distinguished in the centre. A slender stalk or peduncle attaches the corpuscle to the branch of nerve with which it is connected. The peduncle contains a single tubular nerve-fibre ensheathed in filamentous connective tissue, with one or more fine blood-vessels; and it joins the corpuscle at or near one end, and conducts the nerve-fibre into it. The little body itself, examined under the microscope, is found to have a beautiful lamellar structure (fig. XC, A). It consists, in fact, of numerous concentric membranous capsules incasing each other like the coats of an onion, with a small quantity of pellucid fluid included between them. Surrounded by these capsules, and occupying a cylindrical cavity in the middle of the corpuscle, is the core, formed of transparent and homogeneous soft substance, in the midst of which the prolongation of the nerve-fibre is contained. The number of capsules is various; from forty to sixty may be counted in large corpuscles. The series immediately following the central or median cavity, and comprehending about half of the entire number, are closer together than the more exterior ones, seeming to form a system by themselves, which gives rise to a white streak often distinguishable by the eye along the middle of the corpuscles when seen on a dark ground. Outside of all, the corpuscle has a coating of ordinary connective tissue. The capsules, at least the more superficial ones, consist each of an internal layer of longitudinal and an external of circular fibres, which resemble the white fibres of areolar and fibrous tissue, with cell-nuclei attached here and there on the inner layer, and a few branched fibres of the yellow or elastic kind running on the outer. The nerve-fibre, conducted along the centre of the stalk, enters the corpuscle, and passes straight into the central cavity, at the further end of which it terminates.

Fig. LXXXIX.

Fig. LXXXIX. — A Nerve of the Middle Finger, with Pacinian Bodies attached. Natural size (after Henle and Kölliker).

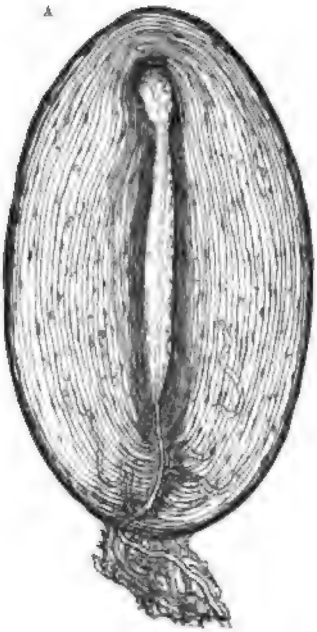
The fibrous neurilemma surrounding the nerve-fibre in the peduncle accompanies it also in its passage through the series of capsules, gradually decreasing in thickness as it proceeds, and ceasing altogether when the nerve has reached the central cavity. According to Pacini, with whom Reichert agrees in this particular, the neurilemma forms a series of concentric cylindrical layers, which successively become continuous with, or rather expand into the capsules, the innermost, of course, advancing farthest. Others suppose that the capsules are all successively perforated by a conical channel which gives passage to the nerve with its neuri-

* Anat. Untersuchungen; Hanover, 1861, and Zeits. f. rat. Med. xvii. 1865.
† Zeits. f. Wiss. Zool. xiii. 1863.

lemma, but at the same time has its own proper wall, round which, on the outside, the capsules are attached. Whichever view may be correct, the capsules are, as it were, strung together where the nerve passes through them, and each intercapsular space, with its contained matter, is shut off from the neighbouring ones. The nerve-fibre, the disposition of which must now be noticed, is single as it runs along

Fig. XC.

A



B

C

A, Magnified View of a Pacinian Body from the Mesentery of a Cat, showing the lamellar structure, the capsules with their nuclei, the inner and closer series of capsules appearing darker in the figure, the nerve-fibre passing along the peduncle, and penetrating the capsules to reach the core in the central cavity, where it loses its strong, dark outline, and terminates by an irregular knob at the distal and here dilated end of the cavity. Connective tissue (neurilemma or perineurium) and blood-vessels are represented in the peduncle, and tortuous capillaries are seen running up among the capsules. B and C represent the termination of the nerve with the distal end of the central cavity and adjoining capsules, to illustrate varieties of arrangement. In B the fibre, as well as the core and adjoining capsules, is bifurcated.

the peduncle, unless when the latter supports two corpuscles; it retains its dark double contour until it reaches the central cavity, where, diminished in size, and freed from its perineurium, it becomes somewhat flattened, and presents the appearance either of a pale, finely granular, and very faintly-outlined band or stripe, little narrower than the previous part of the fibre, or of a darker and more sharply defined narrow line; differing thus in appearance according as its flat side or its edge is turned towards the eye. The pale aspect which the fibre presents in the centre of the corpuscle has with some probability been ascribed to its losing the white substance or medullary sheath on entering the cavity. Henle and Kölliker, however, think that it is more likely the result merely of a diminution in size, together with a certain degree of flattening. It sometimes happens that the fibre regains its original magnitude and double contour for a short space, and changes again before it terminates; this is especially liable to occur while it passes through a sharp flexure in a crooked central cavity. The fibre ends by a sort of knob at the further extremity of the median cavity, which is often itself somewhat dilated. In

many cases, the fibre, before terminating, divides into two branches, as represented in figure B: a division into three has been observed, but this is very rare. In case of division of the fibre, the cavity is generally, but not invariably, divided in a corresponding measure, and the inner set of capsules present a figure in keeping with it. It is worthy of remark, that the nerve-fibre in its course along the cavity runs almost exactly in the axis of the channel, and it maintains this position even when passing through the abrupt flexures of an irregularly-shaped cavity. It sometimes happens that a fibre passes quite through one corpuscle and terminates in a second, resuming its original size and dark outline while passing from the one to the other. Pappenheim states that he has seen a nerve-fibre going through two Pacinian bodies without terminating in either, but returning again to the parent nerve in form of a loop. Other varieties occur, for an account of which the reader is referred to the several authorities already mentioned. A little artery enters the Pacinian bodies along with the nerve, and soon divides into capillary branches, which pierce the parietes of the passage and run up between the capsules. Mr. Bowman finds that they then form loops, and return by a similar route into a vein corresponding to the artery: he states also that a single capillary usually accompanies the nerve as far as the central capsule, and passes some way on its wall, sometimes in a spiral direction.

There is considerable difference of opinion as to the condition of the nerve-fibre in the Pacinian body. Kölliker thinks that it retains its primitive sheath, and is not wholly deprived of its medulla; and that the surrounding core is composed of a nearly homogeneous connective tissue, in which he has seen faintly-marked nuclei and faint longitudinal striation. Engelmann, on the other hand, considers the core to be an expansion of the medullary sheath of the nerve, and ascribes the appearances noticed by Kölliker to changes occurring in the originally homogeneous medulla, as in the case of a white nerve-fibre. The pale fibre within he considers to be simply the axis-cylinder. The core and pale fibre of the end-bulbs he regards in precisely the same way, and thinks it not improbable that the touch-corpuscles will be found to conform. He looks upon the simple capsule of the end-bulb as a development of the primitive nerve-sheath, to which, in the Pacinian bodies, is superadded a series of concentric coats of connective tissue. Engelmann, besides adducing other arguments, refers especially to the structure of the Pacinian bodies of birds, as affording material evidence in support of his view.

Nothing positive is known concerning the special purpose in the animal economy which these curious appendages of the nerves are destined to fulfil. In an anatomical sense a Pacinian body might be viewed as a more complex development of an end-bulb, from which it differs chiefly in the multiplied layers of the capsule. W. Krause endeavours to show that the series of concentric capsules with interposed fluid is an arrangement for converting the effect of mechanical traction into fluid pressure upon the nerve, so that tension and traction of the tissue in which the corpuscle is placed, may be felt and appreciated as ordinary pressure. Their presence in the mesentery of the cat seems, at first sight, against their importance as sentient organs, but it turns out upon trial, that the part in question is remarkably sensitive.

C. Other terminations of sensory nerves.

a. In hair-follicles. By far the majority of the nerves of the skin end in hair-follicles. Up to their entrance, at least, they retain their dark borders, but their arrangement within and actual mode of termination are unknown.

b. In the teeth. Dark bordered nerve-fibres, in fine bundles, enter the teeth and pass into the tooth-pulp; but their mode of termination has not been clearly made out.

c. In organs of special sense. For the peripheral distribution of the optic and acoustic nerves, and the elaborate apparatus in the eye and ear with which they are connected, the reader is referred to the details given in the special anatomy of these organs. Respecting the more simple termination of the olfactory nerve, it has been shown by Max Schultze, that on the olfactory membrane, alongside columnar epithelium cells, there are special nucleated cells of a fusiform shape, and probably of a nervous nature (*olfactory cells*), from which proceed a superficial and a deep process, often presenting a beaded appearance like varicose nerve-fibres. The superficial processes end abruptly at the surface of the epithelium between the columnar cells; the deep and more slender processes pass vertically inwards. They are probably continued from terminal fibres of the olfactory nerve, but the continuity has not been actually traced.

An analogous arrangement is described by Axel Key as discoverable in the fungiform papillæ of the frog's tongue. Among non-ciliated columnar epithelium cells are fusiform *gustatory cells*, having, like the olfactory cells, fine rod-like processes reaching to the surface, and slender, varicose, central filaments. which seem to be continuous with pale fibrils, into which the axis-cylinder of the gustatory nerve-fibres finally divides; and in such way that one axis cylinder may be connected with several cells.

d. In epithelium.—Hoyer believes he has seen fine, pale filaments continued from the plexus of the cornea into the epithelium covering its anterior surface, where they appeared to pass between the cells. Von Heusen describes and figures exquisitely fine filaments connected with the nucleoli of epithelium cells on the tadpole's tail. He finds evidence to satisfy him that their filaments are continued from the cutaneous nerves, which he therefore conceives to run out into epithelium cells as their terminal organs, and end in the nucleoli.

e. In glands.—The termination of nerves in secreting glands will be most conveniently given in the account of the structure of these organs. In the meantime it may be stated that Pflüger has traced nerve fibres to the nuclei of the cells which line the terminal saccules of the salivary glands.

Termination of nerves in muscles:—

A. *In plain or unstriped muscle.*—Dr. Beale, and, after him, Dr. Klebs, have described the nerves of the muscular coat of the frog's bladder as finally distributed in networks of pale fibres, with nuclei. The networks are at first coarser, with larger grey fibres made up of coalesced fibrils (fibrillar fibres), and from these proceed finer bundles and single fibrils, forming closer reticulations, constituting the intra-muscular plexus, which is disposed among the muscular fasciculi and fibre-cells. A more intimate relation to the latter could not be traced with certainty, although Klebs met with a single instance of a nerve-fibril entering a muscular fibre-cell. The nerves distributed to the middle or muscular coat of the arteries are, according to Beale, disposed in a similar plexiform manner; and Julius Arnold has since found a terminal pale nervous network of the same kind in the iris of the rabbit.

B. *In voluntary muscle. a. By Plexuses.*—As mentioned in the account of the muscular tissue, the nerves in the voluntary muscles form plexuses, of which the branches grow finer and the meshes closer as they advance further into the tissue. The individual fibres, while still associated in small bundles, undergo division (fig. LXXXV.), and at length single dark-bordered fibres pass off to the muscular fibres. These nerve-fibres on approaching or reaching a muscular fibre divide still further. As to their ulterior and final distribution, there is great divergence in the statements of very able observers. Beale and Kölliker agree in opinion that the fibres lose their dark borders and run further on as pale fibres, which do not penetrate the sarcolemma. Dr. Beale describes these pale fibres, in the mouse and frog, as distributed in a fine network, bearing nuclei, adhering to, but outside, the sarcolemma, and extending over a great length of the muscular fibre. Kölliker, whose observations were made on the frog, found the fibres apparently to terminate by free ends; at the same time, having seen, here and there, indications, although imperfect, of a fine network, such as he had observed in the electric organ of the torpedo, he is not disposed to exclude the possibility of such mode of termination.

b. By terminal organs.—Since the publication of Beale and Kölliker's observations, a very different account has been given by Rouget—namely, that the muscular nerves end in peculiar terminal organs, which have been named the *motorial end-plates*, to be seen on the muscular fibres, and his account has been in the main confirmed by various contemporary observers, although some important authorities still hold to a different view. The end-plates are described as small lamelliform objects, of an oval or irregular, and often deeply indented outline; their size varies from $\frac{1}{1800}$ to $\frac{1}{350}$ of an inch, according to the size of the muscular fibre, of which the plate may embrace one-third, or more, of the circumference. There is a question whether these organs are situated without or within the sarcolemma. W. Krause, who adopts the former view, describes the end plate as consisting of a thin lamina of connective tissue, attached by its oval or irregular border to the sarcolemma, with clear non-granular nuclei in it, and a finely granular matter underneath, between it and the sarcolemma, in which the axis-cylinder of the nerve-fibre ends, in form of one, or sometimes more, short pale fibres, with free and swollen extremities; whilst the medullary sheath ceases, and the primitive sheath

is continued into the covering lamina of connective tissue. On the other hand, Rouget, Kühne, and most of those who have given descriptions of the organs in question, maintain that the end plate is within the sarcolemma, interposed between it and the proper muscular substance. According to their descriptions, the ultimate nerve-fibre, on reaching the muscular fibre, either immediately or after running but a short way on the surface, sends its axis-cylinder through the sarcolemma to spread out into the plate, whilst the primitive (or perhaps perineural) sheath joins the sarcolemma, and the medullary sheath, which continues on the still dark bordered fibre up to this point, here abruptly ceases. The proper substance of the plate, usually lobed at its circumference (Kühne), is continuous with the axis-cylinder, and is mostly held to be an expansion of it, for it is said to have the same homogeneous or, at most, faintly granular aspect, and to agree with it in optical and micro-chemical characters. Around and beneath this lamina is a bed of granular matter, with large imbedded nuclei having one or more bright nucleoli. The sarcolemma over the seat of the end-plate, and the plate itself, are slightly raised above the general surface, so that the whole structure has been designated by Kühne as the *nerve-eminence* (Nerven-hügel). It would appear that a muscular fibre has but one terminal organ, and receives consequently but one nerve-fibre, so that, allowing the muscular fibre to be one inch and a half long, a considerable length must be governed by one terminal nerve-fibre. As, moreover, the fibres of a nerve undergo division, probably repeated division, before ending, it follows that one fibre in a nerve-root or trunk may supply several muscular fibres. The motorial end-plates have now been recognised in mammalia, birds, and scaly reptiles, and, in a modified form, in various invertebrata.*

Differences of cerebro-spinal Nerves.—It remains to notice the differences which have been observed among the cerebro-spinal nerves in regard to the size of their fibres, and the proportionate amount of the different kinds of fibres which they respectively contain.

As already stated, both white and grey fibres exist in cerebro-spinal nerves, and those of the former kind differ greatly from each other in size. Volkman and Bidder, who have bestowed much pains in endeavouring to arrive at an approximate estimate of the relative amount of the large and the small fibres in different nerves, give the following as the more important results of their researches:—

1. The nerves of voluntary muscles have very few small fibres, usually in not larger proportion than about one to ten.

2. In the nerves of involuntary muscles, whether derived immediately from the cerebro-spinal system or from the sympathetic, the small fibres eminently preponderate, being about a hundred to one.

3. The nerves going to the integuments have always many small fibres, at least as many small as large.

4. Nerves of sentient parts of mucous membranes have from five to twenty times more small fibres than large: in mucous membranes possessing little sensibility, the nerves are made up chiefly of small fibres. The nerves distributed in the pulp of the teeth consist principally of large fibres.

It is plain, however, that Volkmann and Bidder must have reckoned in with their small fibres more or fewer of the non-medullated sort, so that the proportion assigned to the small fibres in their estimate must be taken as including some grey, as well as white fibres; and this agrees with the observation previously made by Remak, that many more grey fibres are contained in the cutaneous than in the muscular nerves. The roots of the spinal nerves contain fine fibres, but according to Remak only in very small proportion: Volkmann and Bidder state that in man the anterior roots contain proportionally more large fibres than the posterior. In almost all nerves the fibres diminish in size as they approach their termination.

The fibres of the optic nerve for the most part resemble the white fibres of the brain, and readily become varicose. The same is true of the acoustic nerve, from its

* For further information on the termination of the nerves, see the Croonian Lectures, by Professor Kölliker, Proceedings of the Royal Society, 1862, and by Dr. Beale, ibid., 1865; also a discussion of the question by Dr. B. in his "Archives of Medicine" for 1865.

origin to its entrance into the internal auditory foramen, where it becomes fasciculated; also of the intra-cranial part of the olfactory, which, however, contains in addition grey matter and nerve-cells, and may, indeed, be reckoned as part of the brain. The branches of the olfactory in the nose are almost wholly made up of fibres bearing nuclei, and having all the outward characters of the grey fibres, like which, also, they cohere or cling fast together in the bundles which they form. Some branches seem to consist entirely of such fibres; others contain a few white fibres intermixed, which, however, may be derived from the nasal branches of the fifth pair.

OF THE SYMPATHETIC OR GANGLIONIC NERVE.

This name is commonly applied to a nerve or system of nerves present on both sides of the body, and consisting of the following parts, viz.:—1. A series of ganglia, placed along the spinal column by the side of the vertebræ, connected with each other by an intermediate nerve-cord, and extending upwards to the base of the skull and downwards as far as the coccyx. This principal chain of ganglia, with the cord connecting them, forms what is often named the trunk of the sympathetic. 2. Communicating branches, which connect these ganglia or the intermediate cord with all the spinal and several of the cranial nerves. 3. Primary branches passing off from the ganglionic chain or trunk of the nerve, and either bestowing themselves at once, and generally in form of plexuses, on the neighbouring blood-vessels, glands, and other organs, or, as is the case with the greater number, proceeding in the first instance to other ganglia of greater or less size (sometimes named præ-vertebral) situated in the thorax, abdomen, and pelvis, and usually collected into groups or coalescing into larger ganglionic masses near the roots of the great arteries of the viscera. 4. Numerous plexuses of nerves, sent off from these visceral or prævertebral ganglia to the viscera, usually creeping along the branches of arteries, and containing in various parts little ganglia disseminated among them. Some of these plexuses also receive contributions from spinal or cerebral nerves, by means of branches which immediately proceed to them without previously joining the main series of ganglia.

Structure of the sympathetic nerve.—The nervous cords of the sympathetic consist of white fibres, and of pale or grey fibres mixed with a greater or less amount of filamentous connective tissue, and inclosed in a common external fibro-areolar sheath. The white fibres differ greatly from each other in thickness. A few are of large size, ranging from $\frac{1}{2000}$ to $\frac{1}{1500}$ of an inch; but the greater number are of much smaller dimensions, measuring from about $\frac{1}{8300}$ to $\frac{1}{4300}$ of an inch in diameter, and, though having a well-defined sharp outline, for the most part fail to present the distinct double contour seen in the larger and more typical examples of the tubular fibre. The pale, non-medullated fibres, have partly the characters of Remak's grey fibres, already described, and often look as if they were really made up of exquisitely fine fibrils; but there are also pale fibres of much less thickness, which, at short distances, are interrupted by, or might be said to swell out into, fusiform nuclei.

The more grey-looking branches or bundles of the sympathetic consist of a large number of the pale fibres mixed with a few of the dark-bordered kind; the whiter cords, on the other hand, contain a proportionally large amount of white fibres, and fewer of the grey; and in some parts of the nerve grey fasciculi and white fasciculi, respectively constituted as above described, run alongside of each other in the same cords for a considerable space without mixing. This arrangement may be seen in some of the branches of communication with the spinal nerves, in the trunk or cord

which connects together the principal chain of ganglia, and in the primary branches proceeding from thence to the viscera. In the last-mentioned case the different fasciculi get more mixed as they advance, but generally it is only after the white fasciculi have passed through one or more ganglia that they become thoroughly blended with the grey; and then, too, the nervous cords receive a large accession of grey fibres (apparently derived from the ganglia), which are mixed up with the rest, and take off more and more from their whiteness.

Relation of the sympathetic to the cerebro-spinal nerves.—We have next shortly to consider the relation between the sympathetic and the cerebro-spinal system of nerves. On this important question two very different opinions have long existed, in one modification or another, amongst anatomists. 1. According to one, which is of old date, but which has lately been revived and ably advocated by Valentin, the sympathetic nerve is a mere dependency, offset, or embranchment of the cerebro-spinal system of nerves, containing no fibres but such as centre in the brain and cord, although it is held that these fibres are modified in their motor and sensory properties in passing through the ganglia in their way to and from the viscera and involuntary organs. 2. According to the other view, the sympathetic nerve (commonly so called) not only contains fibres derived from the brain and cord, but also proper or intrinsic fibres which take their rise in the ganglia; and in its communications with the spinal and cranial nerves, not only receives from these nerves cerebro-spinal fibres, but imparts to them a share of its own proper ganglionic fibres, to be incorporated in their branches and distributed peripherally with them. Therefore, according to this latter view, the sympathetic nerve, commonly so called, though not a mere offset of the cerebro-spinal nerves, yet, receiving as it does a share of their fibres, is not wholly independent, and for a like reason the cerebro-spinal nerves (as commonly understood) cannot be considered as constituted independently of the sympathetic; in short, both the cerebro-spinal and the sympathetic are mixed nerves, that is, the branches of either system consist of two sets of fibres of different and independent origin, one connected centrally with the brain and cord, the other with the ganglia. Hence, if we look to the central connection of their fibres as the essential ground of distinction among nerves, the cerebro-spinal system of nerves might, strictly speaking, be considered as consisting of and comprehending all the fibres having their centre in the cerebro-spinal axis, whether these fibres run in the nerves usually denominated cerebral and spinal, or are distributed to the viscera in the branches of the nerve usually named the sympathetic; and, on the same ground, the sympathetic or ganglionic system, strictly and properly so called, would consist of and comprehend all the fibres connected centrally with the ganglia, wherever such fibres exist and into whatever combinations they enter, whether proceeding to the viscera or distributed peripherally with the nerves of the body generally; the nerve-fibres which emanate from the ganglia on the roots of the spinal and cerebral nerves being reckoned into the system, as well as those from ganglia, usually denominated sympathetic. While ready, however, to acquiesce in the justice of the above distinction, we do not mean to employ the terms already in use in a sense different from that which is currently received.

In endeavouring to decide between the two views above stated, it may be first observed that the existence in the sympathetic nerve of fibres connected centrally with the cerebro-spinal axis, is proved not only by tracing bundles of fibres from the roots of the spinal nerves along the communicating branches and into the sympathetic, but

by the pain or uneasy sensations which arise from disease or disturbance of organs, such as the intestines, supplied exclusively by what are considered branches of the sympathetic; by experiments on living or recently killed animals, in which artificial irritation of the roots of the spinal nerves, or of various parts of the cerebro-spinal centre, caused movements of the viscera; and by experiments on the sympathetic nerve in the neck, by which it is shown that the dilatation of the pupil and the tonicity of the cutaneous vessels of the head are dependent on fibres which pass along the sympathetic nerve but are centrally connected with the upper part of the spinal cord.

These facts, it is evident, accord with both of the above-mentioned opinions respecting the constitution of the sympathetic; but it may be further shown that this nerve contains fibres which arise from the ganglia and take a peripheral course, so that the second of the two opinions approaches nearer to the truth. In support of this assertion we may adduce the actual observation of nerve-fibres proceeding from the nerve-cells of the ganglia in a peripheral direction only; and there are also other grounds for believing that more fibres pass out of the sympathetic ganglia than can possibly be derived from the brain and cord. This seems to follow from a comparison of the aggregate size of the branches issuing from these ganglia with that of all the branches which can be supposed to enter them. To explain this, however, we must first consider the mode of communication between the sympathetic and spinal nerves.

The branches of communication which pass between the ganglia or gangliated cord of the sympathetic and the spinal nerves, are connected with the anterior and greater branch of each of the latter nerves, a little in advance of the spinal ganglion; and at the point of connection the communicating branch in most cases divides into two portions, one central, running towards the roots of the spinal nerve and the spinal cord, the other, peripheral, taking an outward course along with the anterior branch of the spinal nerve, with which it becomes incorporated and distributed. It can scarcely be doubted that the central portion, whilst it may contain fibres sent by the sympathetic to the spinal nerves or to the spinal cord, must necessarily contain all those which proceed from the cord to the sympathetic, and that, on the other hand, the peripheral division must consist of fibres immediately proceeding from the sympathetic and distributed peripherally with the spinal nerve. It is further observed, that in some of the junctions with the spinal nerves, the central and peripheral divisions of the communicating branch are about equal in size, and that in others the central part is greater than the peripheral, whilst in others, again, the peripheral prevails over the central. Now, in an animal such as the frog, in which the spinal nerves are of small size and few in number, it is possible, with the aid of the microscope, to compare by measurement the central and peripheral divisions of the communicating branch in all the communications between the sympathetic and the spinal nerves, or even to count the fibres when the branches are very fine; and by such a comparison Volkmann and Bidder have shown, that, after making all reasonable deductions and allowances, the whole amount of the fibres, or at least the aggregate bulk of the fasciculi, which obviously pass from the sympathetic and run outwards with the spinal nerves, considerably exceeds that of the central fasciculi which must contain the fibres contributed to the sympathetic from the cerebro-spinal system: and if to these peripheral fibres we add the branches distributed to the viscera, it seems plain that more fibres must proceed from the ganglia than can possibly be supposed to enter them from the spinal nerves or spinal cord, and that consequently the ganglia must themselves be centres in which nerve-fibres take their rise. It is worthy of remark, that in the frog, according to the observations of the anatomists just named, the central division of the communicating cord greatly exceeds the peripheral in the connections with the upper spinal nerves, but that lower down it gradually diminishes, absolutely as well as in comparison with the peripheral, and at length disappears altogether, so that the fasciculi connected with the eighth and ninth spinal nerves are entirely peripheral in their course.

Another circumstance still remains to be noticed respecting the communications of the sympathetic and spinal nerves. It has been long known that in most of these communications there are usually two connecting cords passing between the sympathetic and the spinal nerve; and it has been remarked also by various observers, that these cords contain grey as well as white fasciculi. More recently, however, Todd and Bowman have called attention to the fact that one of the two connecting cords is

altogether of the grey kind, consisting of gelatinous fibres, with, as usual, a very few white or tubular fibres mixed with them; and this observation has since been confirmed by Beck. The other cord either is entirely white, or more commonly, as appears to me, is made up of a white and grey portion running alongside each other. It seems highly probable that the white cords and the white fasciculi of the mixed cords contain the cerebro-spinal fibres which the spinal nerves contribute to the sympathetic, and that the grey cords and fasciculi are contributions from the sympathetic to the spinal nerves. In corroboration of this view, Mr. Beck observes that the grey cords on leaving the ganglia give small branches to the neighbouring vessels, and are reduced in size before joining the spinal nerves. Another interesting fact respecting these communications has been pointed out by the last-named observer somewhat similar to that previously noticed in the frog, namely, that whilst the grey and white connecting cords are in the thorax of nearly equal size, the grey one relatively increases lower down, and in the pelvis constitutes the sole communication between the sacral ganglia of the sympathetic and the spinal nerves, the white branches from the latter to the sympathetic passing over the sacral ganglia without joining them, to enter the sympathetic plexuses sent to the pelvic viscera.

The tubular fibres of each white communicating fasciculus can be traced back to both the anterior and the posterior root of the spinal nerve, and pale fibres from the grey fasciculus may be traced up into the anterior root, and as far as the ganglion of the posterior root, which root has also pale fibres above the ganglion. Whether these central pale fibres proceed from the sympathetic to the spinal cord (possibly to be distributed to its vessels), or are sent from the cord and spinal ganglia to the sympathetic, or pass both ways, is as yet uncertain.

As to the further progress of the cerebro-spinal fibres conveyed to the sympathetic by the communicating branches, Valentin has endeavoured to show that after joining the main gangliated cord or trunk of the sympathetic, they all take a downward direction, and after running through two or more of the ganglia, pass off in the branches of distribution, leaving the trunk considerably lower down than the point where they joined it. He conceives that this arrangement, which he calls "lex progressûs," is proved by experiments on animals, in which he found, that on irritating different parts of the cerebro-spinal axis, as well as different branches of nerves, the visceral movements which followed bore a relation to the point irritated, which corresponded with the notion of such an arrangement. Volkmann and Bidder, on the other hand, show that this opinion cannot be reconciled with the observed anatomical disposition of the fibres, for there are fasciculi from the communicating branches which obviously pass upwards; nor will the experimental evidence in its favour apply to the upper part of the sympathetic, where, as Valentin himself admits, motorial fibres must be supposed to run in an upward direction to account for the contraction of the pupil which follows section of the cervical part of the sympathetic.

From what has been stated it seems reasonable to conclude that nerve-fibres take their rise in the ganglia both of the cerebro-spinal and sympathetic nerves, and are in both kinds of nerves mixed with fibres of cerebral or spinal origin; that the ganglia are nervous centres which may probably receive through afferent fibres impressions of which we are unconscious and reflect these impressional stimuli upon efferent or motor fibres: that perhaps, even, certain motorial stimuli emanate from them, the movements excited by or through the ganglia being always involuntary, and affecting chiefly the muscular parts of the viscera, the sanguiferous, and perhaps the absorbent vessels; and that, in fine, the chief purpose served in the animal economy by the ganglia and the ganglionic nerve-fibres, whether existing in acknowledged branches of the sympathetic, or contained in other nerves, is to govern the involuntary, and, for the most part, imperceptible movements of nutrition, in so far at least as these movements are not dependent on the brain and spinal cord; for it must not be forgotten that there is unquestionable evidence to prove that the visceral and vascular motions are influenced by nerve-fibres connected with the cerebro-spinal centre.

Among various physiologists of consideration, who adopt this view in a more or less modified shape, some have been further of opinion that the fibres of ganglionic origin differ in structure, size, and other physical characters from those which arise in the cerebro-spinal axis. As regards this question, I must confess, that there does not seem to me to be conclusive evidence to show that peculiar anatomical characters are distinctive of the fibres of different origin. It has been already stated that both dark-bordered and pale fibres may be connected with ganglion-cells, and for aught that has been proved to the contrary, all three varieties of fibres spoken of, large tubular, small tubular, and grey, may arise both in the cerebro-spinal axis and in the ganglia; although it is certainly true that the two latter kinds largely predominate in the sympathetic, and abound in other nerves, or branches of nerves, which appear to receive large contributions from ganglia.

VITAL PROPERTIES OF THE NERVOUS SYSTEM.

The fibres of nerves are endowed with the property of transmitting impressions, or the effect of impressions, from the point stimulated towards their central or their peripheral extremities. One class of fibres conduct towards the nervous centres and are named "afferent," their impressions being "centripetal;" another class of fibres conduct towards their distal extremities, which are distributed in moving parts, and these fibres are named "efferent," whilst their impressions are "centrifugal." Impressions propagated centripetally along the nerves to the brain give rise to sensations, varying according to the nerve impressed, and the objective cause of the impression; stimuli transmitted outwardly, on the other hand, are conveyed to muscles, and excite movements. Motorial stimuli thus passing along efferent nervous fibres may emanate from the cerebrum as in voluntary and emotional movements, or possibly from some other central part, as in the case of certain involuntary motions; or such stimuli may be applied in the first instance to afferent fibres, by these conducted to the brain or some other central organ, and then "reflected" by the central organ to efferent fibres, along which they are propagated to the muscle or muscles to be moved; and in this case the intervention of the central organ may give rise to sensation or not, the difference in this respect probably depending on the part of the nervous centre where the reflection takes place.

The property of conducting a stimulus or propagating its effects in a determinate direction, belongs to the fibres of the nerves, and in all probability also to the fibrous part of the nervous centre, while it is probable that to the cells or corpuscles of the grey matter of the central organs, is assigned the office of receiving impressions conveyed from without, and presenting them to the conscious mind, of mediating between the mind and the efferent fibres in excitation of the latter by mental stimuli (as in voluntary and emotional acts), of transferring to efferent fibres stimuli conducted to the centre by afferent fibres in the production of reflex movements, and, possibly, of originating purely corporeal stimuli in certain involuntary motions. In addition to these endowments, the nerves are concerned in controlling and regulating the molecular changes and chemical actions which occur in nutrition, secretion, and other allied processes. It may no doubt be fairly questioned, whether the effect justly attributable to the nerves in such cases is not produced merely through the influence which they exert over the motions of the minute vessels and contractile tissues concerned; but the tendency of late observations on the nerves of secreting glands, and the experiments on the luminiferous organ of the fire-fly, referred to in a

former chapter, is towards the recognition of some more direct operation.

The properties above mentioned, of the nerves and nervous centres, have been commonly ascribed to a peculiar force developed in the nervous system, which has received the names of "nervous force," "nervous principle," "nervous influence," and "vis nervosa" (in the largest sense of that term); and whilst some physiologists consider that force as a species of agency altogether peculiar to living bodies, others have striven to identify it with some of the forces known to be in operation in inanimate nature, or to show its fundamental relationship to them.

The greater number of nerves possess both afferent and efferent fibres, and are named compound or moto-sensory, inasmuch as they minister both to sensation and motion. In such compound nerves the two kinds of fibres are mixed together and bound up in the same sheaths; but in the most numerous and best-known examples of this class, the afferent and efferent fibres, though mixed in the trunk and branches of the nerves, are separated at their roots. This is the case in the spinal nerves: these have two roots, an anterior and posterior, both for the most part consisting of many funiculi, and the posterior passing through a ganglion with which the fibres of the anterior root have no connection. Now it has been ascertained by appropriate experiments on animals, that the anterior root is efferent and contains the motor fibres, and that the posterior is afferent and contains the sensory fibres. The fifth pair of cranial nerves has a sensory root furnished with a ganglion, and a motor root, like the spinal nerves. The glosso-pharyngeal and pneumo-gastric nerves are also decidedly compound in nature; they are also provided with ganglia at their roots, which involve a greater or less number of their fasciculi; but it has not yet been satisfactorily determined whether in these nerves the fibres which have different properties are collected at the roots into separate bundles, nor how they are respectively related to the ganglia. The sympathetic, as already stated, contains both afferent and efferent fibres.

Simple nerves are such as contain either afferent or efferent fibres only. The olfactory, auditory, and optic are simple afferent and sensory nerves. The third, fourth, and sixth, the facial, the spinal accessory and hypoglossal nerves are generally regarded as examples of simple motor nerves; there is reason to believe, at least, that they are simple and motor in their origin, or as far as their proper fibres are concerned, and that the sensibility evinced by some of them in their branches is owing to sensory fibres derived from other nerves which join them in their progress.

The nerves governing the motions of the blood-vessels are commonly spoken of as the "vaso-motorial nerves;" but although this term is often of convenient application, there seems no sufficient reason for reckoning these nerves as a distinct system, any more than motorial nerves distributed to other parts or organs whose motions are independent of the will.

DEVELOPMENT OF NERVES.

The knowledge as yet acquired respecting this process is not very positive or consistent, so that much room is left for speculation and conjecture. The *nerve-cells* are generally said to be derived from the common embryo-cells, which, undergoing modification in their substance, send out branches from their circumference and acquire the character of nerve-cells. As they are sometimes found with double or divided nuclei, it is inferred that they increase in number by division, after the manner of cells generally. According to the most generally current descriptions, the *fibres* are stated to be formed by the linear coalescence of fusiform cells, and to

be at first pale and grey, but afterwards to acquire medulla and become white. This change of aspect is apparent in the human embryo of the fourth or fifth month. Harting considers that the fibres represent at first only naked axis-cylinders, and suggests that the enclosing membranous tube and white substance are produced as an excretion from the axial fibre. According to Kölliker's account of the growth of nerve-fibres at their peripheral ends, as observed in the tail of batrachian larvæ, the existing fibres are prolonged by rows of fusiform cells which coalesce into pale fibres. These send out fine offshoots, which may join with neighbouring fibres, or with branched or stellate cells, which change into branched fibres, and in both of these ways the branching and conjunction of the nerves go on. The first fibres thus generated (embryonal fibres, Köll.) virtually represent bundles of two, three, or more tubular dark-bordered fibres, into which they are speedily converted; the formation of the medullary sheath proceeding outwards along the branches.

Dr. Beale has studied the formation of cells and fibres both in embryo and adult animals, and the following are the principal results of his observations. In both, cells are formed from nuclei imbedded in granular matter; the new-formed cells are connected one to another, and two cells thus connected withdraw from each other, whilst the connecting isthmus lengthens out and becomes a fibre. The fibres accordingly do not sprout out from a previously insulated simple cell, but are spun out of the substance of the cell, or nucleus, with which they are connected from the beginning. Ganglion-cells also increase in number by division into two or more, and in this case the multiplied fibres belonging to the new cells form a bundle corresponding to the nervous stem or peduncle of the original cell. A ganglion cell may also arise from (apparently) a nucleus placed in the course of a fibre, viz., a little oblong granular mass (of germinal matter, Beale) connected at each end with a fibre. This body first clears up at its circumference, then deviates from the straight line, so that the two portions of the fibre originally prolonged from its extremities, come to be connected with it at one side, and finally, by further change in its figure, at one end of it, as two fibres, whilst their continuations in the bundle from which they have been, as it were, looped out, run in opposite directions. The two fibres at first proceed straight from the cell, but afterwards one becomes twisted round the other, and the coils increase with the age of the cell, but the cell-body dwindles as it grows older. A nerve-fibre in a fasciculus may also be formed from two nuclei connected at their ends which withdraw from each other, the connecting thread then lengthening out into a fibre. For further details, Dr. Beale's original memoir may be consulted.*

To the foregoing may be added the chief conclusions arrived at by von Hensen from recent observations on the growing nerves in the tadpole's tail. According to his account, fine nervous branches are seen running out, on the tail-fin, into almost imperceptibly fine filaments. The nerves are at first pale, smooth, without nuclei, and represent the naked axis-cylinders, though much finer. Then nuclei appear upon them, but these belong to very long-drawn fusiform cells which now really *inclose* these axis-cylinders, and form the primitive sheath of the nerve-fibres; but this ensheathment stops before reaching the finest branches, *i.e.*, until they grow larger. Afterwards the medulla appears. According to von Hensen, nerves do not grow from cells—such as cells of a nervous centre—outwards in the direction of their branches. He thinks the mode is thus:—Two nerve-cells are connected by a fibre, or what may be the rudiment of many fibres; of the cells, the one is central, the other eventually becomes a peripheral terminal organ; (as already stated, he believes the cutaneous nerve-fibres to be connected with epithelium cells); the latter, in the progress of growth and development, is withdrawn from the former, and the nerve thus lengthened. Moreover, both cells may divide, and the nerve or fibre splits in correspondence, so that a nerve comes to be connected with several central and several peripheral cells. The peripheral cell or cells may divide more extensively than the central, but as corresponding divisions take place in the nerve-fibres, every peripheral cell or terminal organ maintains its connection with the nervous centre. Von Hensen remarks that the foundation of the nervous centres and of the nerves of special sense, as well as those of the skin, is laid in the corneous layer of the blastoderm, from which both the central and peripheral cells are derived originally. It will be seen that

* Phil. Trans. 1863.

the principle of formation of nerve-fibres advanced by von Hensen is substantially the same as that previously published by Dr. Beale.

Re-union and regeneration of nerves.—The divided ends of a nerve that has been cut across readily reunite, and in process of time true nerve fibres are formed in the cicatrix, and restore the continuity of the nervous structure. The conducting property of the nerve, as regards both motion and sensation, is eventually re-established through the re-united part. But immediately after the section, a process of degeneration begins in the peripheral or severed portion of the nerve. The medulla of the white fibres degenerates into a granular mass consisting, apparently, of fatty molecules, and is then totally removed, while the axial fibre, with the primitive sheath and nuclei, remains; but, according to some authorities, the latter also suffer more or less. After reunion takes place, and usually not till then, the medulla is gradually restored, the restoration proceeding from the point of reunion outwards along the nerve, which is then restored to its primitive integrity both in structure and function. From experiments of Philipeaux and Vulpian, it would seem that in very young animals restoration of the severed portion may take place without previous reunion.

The degeneration above referred to does not affect the part of the nerve remaining in connection with the nervous centre, which seems to exert an influence in maintaining the nutrition of the nerve. The ganglia, as well as the brain and spinal cord, have been shown by Dr. Waller to be centres of this influence. He found that in the central and undegenerated portion of a divided spinal nerve, while the fibres belonging to the anterior root owe their integrity to their connection with the spinal cord, those of the posterior root are similarly dependent on the ganglion; and that if the posterior root be cut between the ganglion and the spinal cord, not only will the fibres which belong to it in the trunk of the nerve beyond the ganglion remain unchanged, but also those above the ganglion, in the portion of the root left in connection with it; whereas the segment of the same root which remains connected with the cord but severed from the ganglion degenerates. Section of the sympathetic nerve in the neck is followed by degeneration of the cephalic segment as high as the superior cervical ganglion, but no farther.

BLOOD-VESSELS.

The blood, from which the solid textures immediately derive material for their nourishment, is conveyed through the body by branched tubes named blood-vessels. It is driven along these channels by the action of the heart, which is a hollow muscular organ placed in the centre of the sanguiferous system. One set of vessels, named *arteries*, conduct the blood out from the heart and distribute it to the different regions of the body, whilst other vessels named *veins* bring it back to the heart again. From the extreme branches of the arteries the blood gets into the commencing branches of the veins or revehent vessels, by passing through a set of very fine tubes which connect the two, and which, though not abruptly or very definitely marked off from either, are generally spoken of as an intermediate set of vessels, and by reason of their smallness are called the *capillary* (*i.e.*, hair-like) *vessels*, or, simply, *the capillaries*.

The conical hollow muscular heart is divided internally into four cavities, two placed at its base, and named auricles, and two occupying the body and apex, named ventricles. The auricles are destined to receive the returning blood from the great veins, which accordingly open into them, and to pass it on into the ventricles; whilst it is the office of the latter to propel the blood through the body. The ventricles have therefore much thicker and stronger sides than the auricles, and the great arterial trunks lead off from them. Each auricle opens into the ventricle of the same side, but the right auricle and ventricle are entirely shut off from those of the left side by an impervious partition placed lengthwise in the heart.

The blood is sent out by the left ventricle into the main artery of the body, named the aorta, and passes through the numerous subordinate

arteries, which are branches of that great trunk, to the different parts of the system, then, traversing the capillaries, it enters the veins, and is returned by two great venous trunks, named the superior and inferior venæ cavæ, to the right auricle. In passing from the arteries to the veins the blood changes in colour from red to dark and is otherwise altered in quality; in this condition it is unfit to be again immediately circulated through the body. On returning, therefore, to the right side of the heart, the blood, now dark and venous, must re-acquire the florid hue and other though less obvious qualities of arterial blood before it is permitted to resume its course. For this purpose, being discharged by the right auricle into the right ventricle, it is driven, by the contraction of that ventricle, along the pulmonary artery and its branches to the lungs, where, passing through the capillary vessels of these organs, it is exposed to the influence of the air, and undergoes the requisite change, and having now become florid again, it enters the commencing branches of the pulmonary veins, which, ending by four trunks in the left auricle convey it into that cavity, whence it is immediately discharged into the left ventricle to be sent again along the aorta and through the system as before.

The blood may thus be considered as setting out from any given point of the sanguiferous system and returning to the same place again after performing a circuit, and this motion is what is properly termed the *circulation* of the blood. Its course from the left ventricle along the aorta, throughout the body, and back by the venæ cavæ to the right ventricle, is named the *greater* or *systemic circulation*, and its passage through the lungs by the pulmonary artery and pulmonary veins from the right to the left side of the heart, is termed the *lesser* or *pulmonary circulation*; but the blood must go through both the greater and the lesser circulation in order to perform a complete circuit, or to return to the point from which it started. As the vessels employed in the circulation through the lungs have been named pulmonary, so the aorta which conveys the blood to the system at large is named the systemic artery, and the venæ cavæ the systemic veins, whilst the two sets of capillaries interposed between the arteries and veins, the one in the lungs, the other in the body generally, are respectively termed the pulmonary and the systemic capillaries.

The blood flows in the arteries from trunk to branches, and from larger to smaller but more numerous tubes; it is the reverse in the veins, except in the case of the *vena portæ*, a vein which carries blood into the liver. This advehent vein, though constituted like other veins in the first part of its course, divides on entering the liver into numereus branches, after the manner of an artery, sending its blood through these branches and through the capillary vessels of the liver into the efferent hepatic veins to be by them conducted into the inferior vena cava and the heart.

The different parts of the sanguiferous system above enumerated may be contemplated in another point of view, namely, according to the kind of blood which they contain or convey. Thus the left cavities of the heart, the pulmonary veins, and the aorta or systemic artery, contain red or florid blood fit to circulate through the body; on the other hand, the right cavities of the heart with the venæ cavæ, or systemic veins, and pulmonary artery, contain dark blood requiring to be transmitted through the lungs for renovation. The former or red-blooded division of the sanguiferous system, commencing by the capillaries of the lungs, ends in the capillaries of the body at large; the latter or dark-blooded part commences in the systemic capillaries and terminates in those of the lungs. The heart

occupies an intermediate position between the origin and termination of each, and the capillaries connect the dark and the red set of vessels together at their extremities, and serve as the channels through which the blood passes from the one part of the sanguiferous system to the other, and in which it undergoes its alternate changes of colour, since it becomes dark as it traverses the systemic capillaries and red again in passing through those of the lungs.

ARTERIES.

These vessels were so named from the notion that they naturally contain air. This error which had long prevailed in the schools of medicine was refuted by Galen, who showed that the vessels called arteries, though for the most part found empty after death, really contain blood in the living body.

Mode of Distribution.—The arteries usually occupy protected situations; thus after coming out of the great visceral cavities of the body they run along the limbs on the aspect of flexion, and not upon that of extension where they would be more exposed to accidental injury.

As they proceed in their course the arteries divide into branches, and the division may take place in different modes. An artery may at once resolve itself into two or more branches, no one of which greatly exceeds the rest in magnitude, or it may give off several branches in succession and still maintain its character as a trunk. The branches come off at different angles, most commonly so as to form an acute angle with the further part of the trunk, but sometimes a right or an obtuse angle, of which there are examples in the origin of the intercostal arteries. The degree of deviation of a branch from the direction of the trunk was supposed to affect the force of the stream of blood, but Weber maintains, that it can produce little or no effect in a system of elastic tubes maintained, like the arteries, in a state of distension.

An artery, after a branch has gone off from it, is smaller than before, but usually continues uniform in diameter or cylindrical until the next secession; thus it was found by Mr. Hunter that the long carotid artery of the camel does not diminish in calibre throughout its length. A branch of an artery is less than the trunk from which it springs, but the combined area or collective capacity of all the branches into which an artery divides, is greater than the calibre of the parent vessel immediately above the point of division. The increase in the joint capacity of the branches over that of the trunk is not in the same proportion in every instance of division, and there is at least one case known in which there is no enlargement, namely, the division of the aorta into the common iliac and sacral arteries; still, notwithstanding this and other possible exceptions, it must be admitted as a general rule that an enlargement of area takes place. From this it is plain, that as the area of the arterial system increases as its vessels divide, the capacity of the smallest vessels and capillaries will be greatest, and as the same rule applies to the veins, it follows that the arterial and venous systems may be represented, as regards capacity, by two cones whose apices (truncated it is true) are at the heart, and whose bases are united in the capillary system. The effect of this must be to make the blood move more slowly as it advances along the arteries to the capillaries, like the current of a river when it flows in a wider and deeper channel, and to accelerate its speed as it returns from the capillaries to the venous trunks.

When arteries unite they are said to anastomose or inosculate. Anasto-

moses may occur in tolerably large arteries, as those of the brain, the hand and foot, and the mesentery, but they are much more frequent in the smaller vessels. Such inosculations admit of a free communication between the currents of blood, and must tend to promote equability of distribution and of pressure and to obviate the effects of local interruption.

Arteries commonly pursue a tolerably straight course, but in some parts they are tortuous. Examples of this in the human body are afforded by the arteries of the lips and of the uterus, but more striking instances may be seen in some of the lower animals, as in the well-known case of the long and tortuous spermatic arteries of the ram and bull. In very moveable parts like the lips this tortuosity will allow the vessel to follow their motions without undue stretching; but in other cases its purpose is not clear. The physical effect of such a condition of the vessel on the blood flowing along it must be to reduce the velocity, by increasing the extent of surface over which the blood moves, and consequently the amount of impediment from friction; still it does not satisfactorily appear why such an end should be provided for in the several cases in which arteries are known to follow a tortuous course. The same remark applies to the peculiar arrangement of vessels named a "rete mirabile," where an artery suddenly divides into small anastomosing branches, which in many cases unite again to reconstruct and continue the trunk. Of such *retia mirabilia* there are many examples in the lower animals, but, as already remarked, the purpose which they serve is not apparent. The best known instance is that named the *rete mirabile of Galen*, which is formed by the intracranial part of the internal carotid artery of the sheep and several other quadrupeds.

Physical Properties.—Arteries possess considerable strength and a very high degree of elasticity, being extensible and retractile both in their length and width. When cut across, they present, although empty, an open orifice; the veins, on the other hand, collapse, unless when prevented by connection with surrounding rigid parts.

Structure.—In most parts of the body the arteries are inclosed in a sheath formed of connective tissue, and their outer coat is connected to the sheath by filaments of the same tissue, but so loosely that when the vessel is cut across its ends readily shrink some way within the sheath. The sheath may inclose other parts along with the artery, as in the case of that enveloping the carotid artery, which also includes the internal jugular vein and pneumo-gastric nerve. Some arteries want sheaths, as those for example which are situated within the cavity of the cranium.

Independently of this sheath, arteries (except those of minute size whose structure will be afterwards described with that of the capillaries) have been usually described as formed of three coats, named, from their relative position, internal, middle, and external; and as this nomenclature is so generally followed in medical and surgical works, and also correctly applies to the structure of arteries so far as it is discernible by the naked eye, it seems best to adhere to it as the basis of our description, although it will be seen, as we proceed, that some of these coats are found by microscopic examination really to consist of two or more strata differing from each other in texture, and therefore reckoned as so many distinct coats by some authorities.

Internal coat. This may be raised from the inner surface of the arteries as a fine transparent colourless membrane, elastic but very easily broken, especially in the circular or transverse direction, so that it cannot

be stripped off in large pieces. It is very commonly corrugated with very fine and close longitudinal wrinkles, caused most probably by a contracted state of the artery after death. Such is the appearance presented by the internal coat to the naked eye, but by the aid of the microscope it is found to consist of two different structures, namely: 1. An *epithelium*, forming the innermost part or lining. This is a simple layer of thin elliptical or irregularly polygonal scales, which are often elongated into a lanceolate shape. These epithelial elements have round or oval nuclei, which, however, may disappear; indeed, the whole structure sometimes becomes indistinct, especially in the larger arteries. 2. *Elastic layers.* These form the chief substance of the inner coat. The elastic tissue appears for the most part in form of the "perforated" or "fenestrated" membrane of Henle. This consists of a thin and brittle transparent film, and may exist in one or several layers; and in that case it may be stripped off in small shreds, which have a remarkable tendency to curl in at their upper and lower borders, and roll themselves up as represented in the figure (fig. XCI.). The films of membrane are marked by very fine pale streaks, following principally a longitudinal direction, and joining each other obliquely in a sort of network. Henle considers these lines to be reticulating fibres formed upon the membranous layer. This membrane is further remarkable by being perforated with numerous round, oval, or irregularly-shaped apertures of different sizes. In some parts of the arteries the perforated membrane is very thin, and therefore difficult to strip off; in other situations it is of considerable thickness, consisting of several layers; but it often happens that the deeper layers of the elastic structure, *i. e.*, those farther from the inner surface, lose their membranous character, and pass into a mere network of longitudinal anastomosing fibres of elastic tissue. These longitudinal reticulating fibres are, however, sometimes spoken of as constituting a distinct coat.

Fig. XCI.

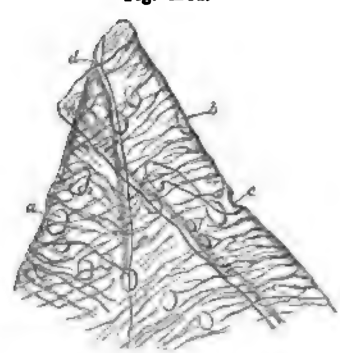


Fig. XCI.—Portion of Fenestrated Membrane from the Crural Artery, magnified 200 diameters (from Henle).

a, *b*, *c*, perforations.

The inner coat may thus be said to be formed of *epithelium* and *elastic layers*; the latter consisting of elastic tissue under two principal forms, namely, the fenestrated membrane and the longitudinal elastic networks: and these two forms may coexist in equal amount, or one may predominate, the other diminishing or even disappearing altogether.

It is further to be observed, that in the inner coat of the aorta and the larger arteries, in addition to the elements described, lamellæ are found of a clear, homogeneous, often striated or sometimes even fibrillated substance, mostly of the nature of connective tissue, and pervaded by longitudinal elastic networks of varying fineness. Immediately beneath the epithelium these transparent layers, the *striated layers* (Kölliker), may contain imbedded nuclei, which have been found by Langhans to belong to branched or irregularly stellate cells; or they may be more uniform and destitute of nuclei, in which case they more resemble elastic membranes.

The vital contractility of small-sized arteries is easily demonstrated in the transparent parts of cold-blooded animals. If the point of a needle be two or three times drawn quickly across one of the little arteries (not capillaries) in the web of a frog's foot placed under the microscope, the vessel will be seen slowly to contract, and the stream of blood passing through it becomes smaller and smaller, and, by a repetition of the process, may be made almost entirely to disappear. After persisting in this contracted state for some minutes, the vessel will gradually dilate again to its original size. The same effect may be produced by the application of ice-cold water, and also by electricity, especially the interrupted electric current. Moreover, if one of the small arteries in the mesentery of a frog or of a small warm-blooded animal, such as a mouse (Poiseuille), be compressed so as to take off the distending force of the blood from the part beyond the point where the pressure is applied, that part will diminish in calibre, at first no doubt from its elasticity, and therefore suddenly, but afterwards slowly. This gradual shrinking of an emptying artery after its elasticity has ceased to operate, may be shown also by cutting out the frog's heart or dividing the main trunks of the vessels: it is obviously due to vital contraction. The contractility of the smaller arteries, as well as its subjection to the influence of the nervous system, is beautifully shown in the experiment of cutting and afterwards stimulating the cervical sympathetic nerve in a cat or rabbit. Immediately after the section, the vessels of the ear become distended with blood from failure of their tonic contraction; but on applying the galvanic stimulus to the upper portion of the nerve, they immediately shrink again, and on interrupting the stimulation they relax as before. The tonic contraction of these vessels appears to be maintained by the spinal cord operating through the branches of the cervical part of the sympathetic nerve; it has been found, moreover, that direct stimulation of the spinal cord causes contraction of other arteries, and probably through branches of spinal nerves.

The contractility of the middle-sized and larger arteries is not so conspicuous, and many excellent observers have failed to elicit any satisfactory manifestation of such property on the application of stimuli to these vessels. Others, however, have observed a sufficiently decided, though by no means a striking degree of contraction slowly to follow mechanical irritation or electric stimulation of these arteries in recently-killed animals. To render this effect more evident, my former colleague, Dr. C. J. B. Williams, adopted a method of experimenting which he had successfully employed to test the irritability of the bronchial tubes. He tied a bent glass tube into the cut end of an artery, and filled the vessel, as well as the bend of the tube with water; the application of galvanism caused a narrowing of the artery, the reality of which was made manifest by a rise of the fluid in the tube. Contraction is said also to follow the application of chemical stimulants, but as these may directly corrugate the tissue by their chemical action, the evidence they afford is less satisfactory. Cold causes contraction of the larger arteries, according to the testimony of various inquirers; and, as in the smaller arteries, a gradual shrinking in calibre ensues in these vessels, when the distending pressure of the blood is taken off, by the extinction or impairment of the force of the heart on the approach of death. From the experiments of Dr. Parry, it would appear that the contraction thus ensuing, proceeds considerably beyond what would be produced by elasticity alone, and that it relaxes after death, when vitality is completely extinct, so that the artery widens again to a certain point, at which it is finally maintained by its elasticity.

VEINS.

Mode of distribution.—The veins are ramified throughout the body, like the arteries, but there are some differences in their proportionate number and size, as well as in their arrangement, which require to be noticed.

In most regions and organs of the body the veins are more numerous and also larger than the arteries, so that the venous system is altogether more capacious than the arterial, but the proportionate capacity of the two cannot be assigned with exactness. The pulmonary veins form an exception to this rule, for they do not exceed in capacity the pulmonary arteries.

The veins are arranged in a superficial and deep set, the former running

immediately beneath the skin, and thence named subcutaneous, the latter commonly accompanying the arteries, and named *venæ comites vel satellites arteriarum.* The large arteries have usually one accompanying vein, and the medium-sized and smaller arteries two; but there are exceptions to this rule; thus, the veins within the skull and spinal canal, the hepatic veins, and the most considerable of those belonging to the bones, run apart from the arteries.

The communications or anastomoses between veins of considerable size, are more frequent than those of arteries of equal magnitude.

Structure.—The veins have much thinner coats than the arteries, and collapse when cut across or emptied; whereas, a cut artery presents a patent orifice. Notwithstanding their comparative thinness, however, the veins possess considerable strength, more even, according to some authorities, than arteries of the same calibre. The number of their coats has been differently reckoned, and the tissues composing them differently described by different writers, and this discrepancy of statement is perhaps partly due to the circumstance that all veins are not perfectly alike in structure. In most veins of tolerable size, three coats may be distinguished, which, as in the arteries, have been named external, middle, and internal.

The *internal coat* is less brittle than that of the arteries, and therefore admits of being more readily peeled off without tearing; but, in other respects, the two are much alike. It consists of an epithelium, a striated lamella containing nuclei, and the usual elastic layers; these occur as dense lamelliform networks of longitudinal elastic fibres, and but seldom as fenestrated membranes.

The *middle coat* is much thinner than that of the arteries, and its muscular tissue has a much larger admixture of white connective tissue. Its fibres are both longitudinal and circular, the one set alternating with the other in layers. The former are well-developed elastic fibres, longitudinally reticulating; the circular layers consist of bundles of muscular fibre-cells and white connective tissue, mixed with a smaller proportion of fine elastic fibres. In medium-sized veins the middle coat contains several successions of the circular and longitudinal layers, but the latter are all more or less connected together by elastic fibres passing through the intervening circular layers. In the larger veins the middle coat is less developed, especially as regards its muscular fibres, but in such cases the deficiency may be supplied by muscularity of the outer coat. Kölliker states that the middle coat is wanting altogether in most of the hepatic part of the vena cava, and in the great hepatic veins; and even where its thickness is considerable, it is less regularly or not at all disposed in layers, and its muscular fibres are more scanty. The muscularity *of the middle coat* is best marked in the splenic and portal veins; it is apparently wanting in certain parts of the abdominal cava and in the subclavian veins.

The *external coat* is usually thicker than the middle coat; it consists of connective tissue and longitudinal elastic fibres. In certain large veins, as pointed out by Remak, this coat contains a considerable amount of plain or non-striated muscular tissue. The muscular elements are well marked in the whole extent of the abdominal cava, in which they form a longitudinal network, occupying the inner part of the external coat; and they may be traced into the renal, azygos, and external iliac veins. The muscular tissue *of the external coat* is also well developed in the trunks of the hepatic veins and in that of the vena portæ, whence it extends into the splenic and superior mesenteric.

Other veins present peculiarities of structure, especially in respect of muscularity. 1. The striated muscular fibres of the auricles of the heart are prolonged for some way on the adjoining part of the venæ cavæ and pulmonary veins. 2. The plain muscular tissue is largely developed in the veins of the gravid uterus, and is described as being present in all three coats. 3. On the other hand, muscular tissue is wanting in the following veins, viz., *a*, those of the maternal part of the placenta; *b*, most of the veins of the brain and pia mater; *c*, the veins of the retina; *d*, the venous sinuses of the dura mater; *e*, the cancellar veins of the bones; *f*, the venous spaces of the corpora cavernosa. In most of these cases the veins consist merely of an epithelium and a layer or layers of connective tissue more or less developed; in the corpora cavernosa the epithelium is applied to the trabecular tissue. It may be added that in the thickness of their coats the superficial veins surpass the deep, and the veins of the lower limbs those of the upper.

The coats of the veins are supplied with nutrient vessels, *vasa vasorum*, in the same manner as those of the arteries. *Nerves* have not been demonstrated in the coats of veins generally, but small branches have been traced on some of the larger veins.

Vital properties.—Veins, when in a healthy condition, appear to be almost devoid of sensibility. They possess vital contractility, which shows itself in the same manner as that of the arteries, but is greatly inferior in degree, and much less manifest. The muscular parts of the great veins, near the auricles of the heart, on being stimulated, in recently killed quadrupeds, exhibit quick and decided contractions, somewhat resembling those of the auricles themselves. Mr. Wharton Jones has discovered a rhythmic pulsation in the veins of the bat's wing, the pulsation occurring from ten to twelve times in a minute; and it is worthy of note that the muscular tissue of these veins appears to be of the plain or unstriped variety.

Valves.—Most of the veins are provided with valves, a mechanical contrivance beautifully adapted to prevent the reflux of the blood. The valves are formed of semilunar folds of the lining membrane, strengthened by included connective tissue, which project obliquely into the vein. Most commonly two such folds or flaps are placed opposite each other (fig. XCIII. A); the convex border of each, which, according to Haller, forms a parabolical curve, is connected with the side of the vein; the other edge is free, and points towards the heart, or at least in the natural direction of the current of the blood along the vessel, and the two flaps obliquely incline towards each other in this direction. Moreover, the wall of the vein immediately above (or nearer the heart than) the curved line of attachment of the valves, is dilated into a pouch or *sinus* on either side (fig. XCIII. B *a*), so that when distended with blood or by artificial injection, the vessel bulges out on each side, and thus gives rise to the appearance of a knot or swelling wherever a valve is placed (as in fig. C). From the above description, it is plain that the valves are so directed as to offer no obstacle to the blood in its

Fig. XCIII.

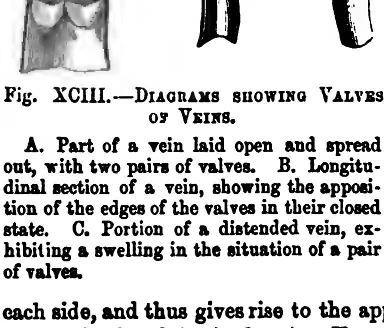


Fig. XCIII.—Diagrams showing Valves of Veins.

A. Part of a vein laid open and spread out, with two pairs of valves. B. Longitudinal section of a vein, showing the apposition of the edges of the valves in their closed state. C. Portion of a distended vein, exhibiting a swelling in the situation of a pair of valves.

onward flow, but that when from pressure or any other cause it is driven backwards, the refluent blood, getting between the dilated wall of the vein and the flaps of the valve, will press them inwards until their edges meet in the middle of the channel and close it up.

The valvular folds are usually placed in pairs as above described; in the veins of the horse and other large quadrupeds three are often found ranged round the inside of the vessel; but this rarely occurs in the human body. On the other hand, the valves are placed singly in some of the smaller veins, and in large veins single valves are not unfrequently placed over the openings of smaller entering branches; also in the right auricular sinus of the heart there is a single crescentic fold at the orifice of the vena cava inferior, and another more completely covering the opening of the principal coronary vein.

Many veins are destitute of valves. Those which measure less than a line in diameter rarely, if ever, have them. In man, valves are wanting in the trunks of the superior and inferior venæ cavæ, in the trunk and branches of the portal vein, in the hepatic, renal and uterine veins; also in the spermatic veins of the female. In the male, these last mentioned veins have valves in their course, and in either sex a little valve is occasionally found in the renal vein, placed over the entrance of the spermatic. The pulmonary veins, those within the cranium and vertebral canal, and those of the cancellated texture of bone, as well as the trunk and branches of the umbilical vein, are without valves. Valves are not generally found, and when present are few in number, in the azygos and intercostal veins. On the other hand, they are numerous in the veins of the limbs (and especially of the lower limbs), which are much exposed to pressure in the muscular movements or from other causes, and have often to support the blood against the direction of gravity. No valves are met with in the veins of reptiles and fishes, and not many in those of birds.

CAPILLARY VESSELS.

That the blood passes from the arteries into the veins was of course a necessary part of the doctrine of the circulation, as demonstrated by Harvey; but the mode in which the passage takes place was not ascertained until some time after the date of his great discovery. The discovery of the capillary vessels, and of the course of the blood through them, was destined to be one of the first-fruits of the use of the microscope in anatomy and physiology, and was reserved for Malpighi (in 1661).

When the web of a frog's foot is viewed through a microscope of moderate power (as in fig. XCIV.), the blood is seen passing rapidly along the small arteries, and thence more slowly through a net-work of finer channels, by which it is conducted into the veins. These small vessels, interposed between the finest branches of the arteries and the commencing veins, are the capillary vessels. They may be seen also in the lungs or mesentery of the frog and other batrachians, and in the tail and gills of their larvæ: also in the tail of small fishes; in the mesentery of mice or other small quadrupeds; and generally, in short, in the transparent vascular parts of animals which can readily be brought under the microscope. These vessels can also be demonstrated by means of fine injections of coloured material, not only in membranous parts, such as those abovementioned, but also in more thick and opaque tissues, which can be rendered transparent by drying.

The capillary vessels of a part are most commonly arranged in a network, the branches of which are of tolerably uniform size, though not all strictly equal; and thus they do not divide into smaller branches like the arteries, or unite into larger ones like the veins; but the diameter of the tubes, as well as the shape and size of the reticular meshes which they form, differs in

different textures. Their prevalent size in the human body may, speaking generally, be stated at from $\frac{1}{3500}$ to $\frac{1}{2000}$ of an inch, as measured when naturally filled with blood. But they are said to be in some parts considerably smaller, and in others larger than this standard: thus, Weber has measured injected capillaries in the brain, which he found to be not wider than $\frac{1}{4700}$ of an inch, and Henle has observed some still smaller,—in both cases apparently smaller than the natural diameter of the blood corpuscles. The capillaries, however, when deprived of blood, probably shrink in calibre immediately after death; and this consideration, together with the fact that their distension by artificial injection may exceed or fall short of what is natural, should make us hesitate on such evidence to admit the existence of vessels incapable of receiving the red particles of the blood. The diameter of the capillaries of the marrow, or of the medullary membrane, is stated as high as $\frac{1}{1200}$ of an inch. In other parts, their size varies between these extremes: it is small in the lungs, small also in muscle; larger in the skin and mucous membranes. According to Mr. Toynbee, the extreme branches of the arteries and the commencing veins in certain parts of the synovial membranes are connected by loops of vessels, which are dilated at their point of flexure to a greater size even than the vessels which they immediately connect.

Fig. XCIV.

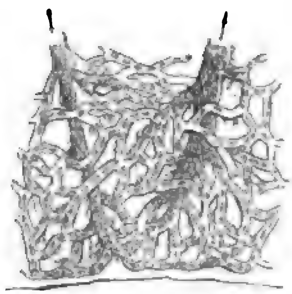


Fig. XCIV. — Capillary Blood-Vessels in the Web of a Frog's Foot, as seen with the Microscope (after Dr. Allen Thomson).

The arrows indicate the course of the blood.

There are differences also in the size or width of the meshes of the capillary network in different parts, and consequently in the number of vessels distributed in a given space, and the amount of blood supplied to the tissue. The network is very close in the lungs and in the choroid coat of the eye, close also in muscle, in the skin, and in most parts of the mucous membrane, in glands and secreting structures, and in the grey part of the brain and spinal cord. On the other hand, it has wide meshes and comparatively few vessels in the ligaments, tendons, and other allied textures. In infants and young persons, the tissues are more vascular than in after-life; growing parts, too, are more abundantly supplied with vessels than those which are stationary.

The figure of the capillary network is not the same in all textures. In many cases the shape of the meshes seems accommodated to the arrangement of the elements of the tissue in which they lie. Thus in muscle, nerve, and tendon, the meshes are long and comparatively narrow, and run conformably with the fibres and fasciculi of these textures (fig. xcv.). In other parts the meshes are rounded or polygonal, with no one dimension greatly predominating (fig. xcvi.). In the smaller-sized papillæ of the skin and mucous membranes, the vessels of the network are often drawn out into prominent loops.

Structure of the small-sized vessels and capillaries.—The capillary vessels have real coats, and are not mere channels drilled in the tissue which they pervade, as has sometimes been maintained. In various parts they are readily separable from the surrounding substance, as in the brain and

retina, and in such cases it is easy to display their independent membranous parietes. The number as well as the structure of the coats of the capillaries differs according to the size of the vessels. Capillaries of a diameter less than $\frac{1}{2400}$ of an inch, were until lately believed to have but a single coat, formed of simple homogeneous transparent membrane, with nucleiform corpuscles attached to it or inclosed in its substance; but from recent researches (by Auerbach, Eberth, and Chrzonszczewsky,) it has been ascertained that they are furnished with an epithelium, to which the nuclei of the capillary coat really belong. The cells of the epithelium are, as in the larger vessels, flattened into scales and form but a single layer, in which the outline of the scales, or their lines of junction one with another, may be made apparent by nitrate of silver injection; after which the nuclei may be brought into view by acetic acid or carmine (fig. XCVII.). The epithelium scales, which are polygonal in the small arteries and veins (A, V), gradually become oblong or spindle-shaped as they pass into the capillaries, and throughout these vessels the epithelium presents the same characters, only the flattened cells or scales become longer and narrower in the smaller capillaries, and fewer in number in the circumference of the tube. In the brain usually only two cells are to be seen in the cross section of a capillary, but in the large capillaries of the kidney and bladder the number may rise to four or five, and in this case the scales are shorter and broader. At the points of junction of the capillaries the cells are much broader and not spindle-shaped but radiate, with three or four pointed branches fitting in between the cells of the three or four adjoining vessels which meet at the spot (fig. XCVII., *c c'*).

Fig. XCV.

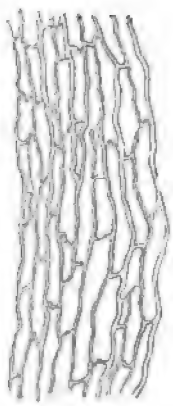


Fig. XCVI.

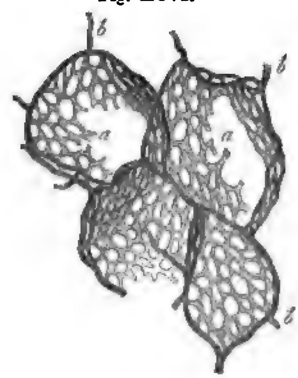


Fig. XCV.—INJECTED CAPILLARY VESSELS OF MUSCLE, SEEN WITH A LOW MAGNIFYING POWER.

Fig. XCVI. — NET-WORK OF CAPILLARY VESSELS OF THE AIR CELLS OF THE HORSE'S LUNG, MAGNIFIED.

a, *a*, capillaries proceeding from *b*, *b*, terminal branches of the pulmonary artery (after Frey).

Auerbach describes the capillary wall as formed entirely of flattened epithelium cells fitted together at their edges into a continuous and coherent membrane, without any further supporting structure; but Chrzonszczewsky discovered portions of the capillaries in which the epithelium cells had been displaced, and where spaces of some extent were left entirely devoid of nuclei and of the outline markings of the cells; and in these parts the outline of the capillary wall was still entire and continuous, and its substance quite structureless. He concludes, therefore, that there is a homogeneous coat and within this an epithelium, to which the nuclei belong.

In vessels one or two degrees larger, there is added on the primitive homogeneous membrane a layer of plain muscular tissue, in form of the usual

Fig. XCVII.

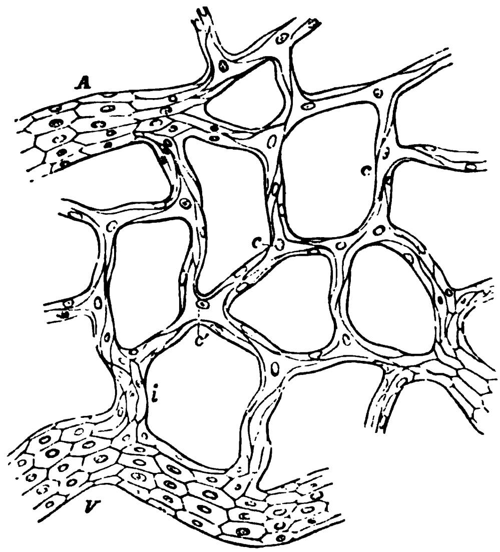


Fig. XCVII.—Magnified View of Capillary Vessels from the Bladder of the Cat.

A, V, an artery and a vein ; *i*, transitional vessel between them and *c c*, the capillaries. The muscular coat of the larger vessels is left out in the figure to allow the epithelium to be seen ; at *c'*, a radiate epithelium scale with four pointed processes, running out upon the four adjoining capillaries (after Chrzonszczewsky, Virch. Arch. 1866).

oblong contractile fibre-cells, which are directed across the diameter of the vessel. The elongated nuclei of these cells may be brought into view by means of acetic acid, as shown in the figure (xcviii.). This layer corresponds with the middle or muscular coat of the arteries. In the smallest vessels in which it appears the muscular cells are few and apart, and a single long cell may turn spirally round the tube ; in larger vessels, especially those of the arterial system, they are of course more densely laid on. Outside the muscular coat is the areolar or connective tissue coat, containing fibres and connective tissue corpuscles, with longitudinally-placed nuclei.

In vessels of $\frac{1}{60}$ of an inch in diameter, or even less, the elastic layers of the inner coat may be discovered (fig. xcviii., A, δ), in form generally of fenestrated membrane, more rarely of longitudinal reticulating elastic fibres ; while the primitive membrane disappears. The small veins, but two or three removes from the capillaries, differ from arteries of corresponding size, chiefly in the inferior development of their muscular tissue.

In reference to the structure of capillaries, it is to be further observed that in parts which are pervaded by a supporting network of retiform connective tissue, such as the substance of the lymphatic glands, the solitary

and agminated intestinal glands and adjacent mucous membrane, etc., the small blood-vessels and capillaries commonly receive a coating of connective tissue corpuscles, which are similar to those of the retiform tissue and connected with the fine trabeculæ of the network, by which the vessels are

Fig. XCVIII.

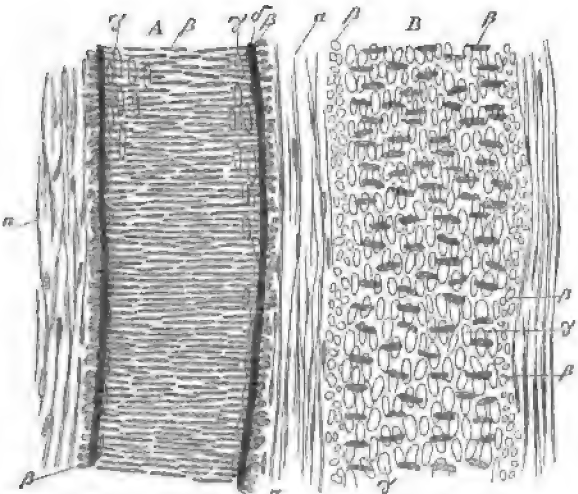


Fig. XCVIII.—A Small Artery A, with a corresponding vein B, treated with Acetic Acid, and magnified 350 diameters (after Kölliker).

α, external coat with oblong nuclei; β, nuclei of the transverse muscular tissue of the middle coat (when seen endwise, as at the sides of the vessel, their outline is circular); γ, nuclei of the epithelium-cells; δ, elastic layers of the inner coat.

thus supported. On the smallest capillaries the corpuscles are but sparingly distributed, but nevertheless afford a continuous covering to the vessel by their finely reticulating outrunners. This coating is named by His, who has most fully described and figured it, the *adventitia capillaris.*

Vital properties.—From the share which the capillaries take in many vital actions, both healthy and diseased, and especially from the part they have been supposed to play in the process of inflammation, much pains has naturally been bestowed to find out whether they are endowed with vital contractility. There is still, however, a difference of opinion on this question; and, while this property evidently exists in vessels, however small, provided with a muscular coat, it has not been shown by equally direct evidence, to belong to the more simply constructed capillaries; and it must be confessed, that the proofs commonly adduced of the existence of vital contractility in these vessels, are ambiguous and inconclusive. These proofs are chiefly the two following: viz., 1st, That stimulants, such as alcohol, oil of turpentine, pepper, and ice or ice-cold water, applied to the frog's foot or mesentery, cause the capillary vessels to shrink in diameter, and that this contraction is speedily followed by their dilatation beyond their natural capacity; the shrinking of the vessels being attributed to the direct operation of the stimuli on their contractility, and their subsequent dilatation to the temporary exhaustion of that property, consequent on its previous undue excitation. 2ndly, That when the vessels are preternaturally dilated, in the way above described, or by the action of ammonia or common salt, they

may, after a time, be made to contract to their usual size by the reapplication of stimuli.

Termination of arteries.—The only known termination of arteries is in veins, and this takes place by means of capillary vessels of some of the forms above described, unless in the maternal part of the placenta, and in the interior of erectile organs, in which it has been supposed that small arteries open into wide venous cavities, without the intervention of capillaries. Additional modes of termination have, however, been assumed to exist. Thus, it was believed that branches of arteries ended in exhalant vessels, which, in their turn, terminated by open orifices on the skin, on the surface of different internal cavities, or in the areolar tissue; other arterial branches were supposed to be continued into the ducts of secreting glands, and it was, moreover, imagined that, besides the red capillaries, there existed finer vessels, which passed between the arteries and the veins, and from their smallness were able to convey only the colourless part of the blood. The existence of these colourless or "serous" vessels, as they were called (*vasa serosa, vasa non rubra*), was held, by most authorities, to be universal; by others it was assumed as necessary, at least, in the colourless textures; but these views have now been generally abandoned, although they long prevailed almost without question, and were made the basis of not a few influential doctrines in pathology and practical medicine. Of course it is not denied, that in growing parts there may be capillaries in an incomplete state of development, which admit only the plasma of the blood.

Erectile, or cavernous tissue.—By this term is understood a peculiar structure, forming the principal part of certain organs which are capable of being rendered turgid, or erected, by distension with blood. It consists of dilated and freely intercommunicating branches of veins, into which arteries pour their blood, occupying the areolæ of a network formed by fibrous, elastic, and probably contractile bands, named trabeculæ, and inclosed in a distensible fibrous envelope. This peculiar arrangement of the blood-vessels scarcely deserves to be regarded as constituting a distinct texture, though reckoned as such by some writers; it is restricted to a very few parts of the body, and in these is not altogether uniform in character; the details of its structure will, therefore, be considered with the special description of the organs in which it occurs.

DEVELOPMENT OF BLOOD-VESSELS.

The first vessels which appear are formed within the ovum, in the germinal membrane; and the process subsequently goes on in growing parts of the animal body. New vessels, also, are formed in the healing of wounds and sores, in the organisation of effused lymph, in the restoration of lost parts, and in the production of adventitious growths. The following may serve as an outline of the process.

The network of vessels which form the vascular area in the germinal membrane of the egg at an early stage of incubation (see page li.), consists of arteries and veins communicating, without capillaries. These vessels are at first solid cylinders of larger or smaller diameter, made up of formative cells cohering together. By liquefaction of their substance in the interior, these cylinders become tubes, and their central cells thus set free are the primitive blood-corpuscles. The uniformly cellular substance forming the wall of the primitive vessels is then converted into the different coats. It is probable that a similar mode of formation of arteries and veins goes on within the body of the embryo as its organs and members are progressively developed; but arteries and veins may also begin as capillaries, which grow into larger vessels, as will presently be explained.

The small vessels and capillaries originate from nucleated cells similar to those which at first constitute the different parts of the embryo. The cell-wall, or envelope, of these cells, shoots out into slender pointed processes, tending in different directions, so that they acquire an irregularly star-shaped or radiated figure. The prolongations from neighbouring cells encounter one another, and join together by their ends, and the irregularly ramified or reticular cavities thus produced are the channels of rudimentary capillaries. In growing parts, such as the tail of batrachian larvæ, where new vessels are formed in the vicinity of those already existing, as represented in the adjoining figure (xcix.) by Kölliker, not only do the processes of the stellate cells join those of neighbouring cells, but some of them meet and join with similar

pointed processes which shoot out from the sides of neighbouring capillary vessels, and in this manner the new vessels are adopted into the existing system. The junctions of the cells with each other or with capillary vessels are, at first, of great tenuity, and contrast strongly with the central and wider parts of the cells; they appear then to be solid, but they afterwards become pervious and gradually widen, blood begins to pass through them, and the capillary network acquires a tolerably uniform calibre. The original vascular network may become closer by the formation of new vessels in its interstices, and this is effected by similarly metamorphosed cells, arising in the areolæ and joining at various points with the surrounding vessels, and also simply by pointed offshoots from the existing capillaries stretching across the intervals and meeting from opposite sides, so as when enlarged to form new connecting arches. From observations made on the fœtal membranes of sheep, Mr. Paget has found that the mode of formation of capillaries described by Kölliker in batrachians, holds good also in mammiferous animals.* The simple homogeneous coat of the capillaries is thus formed out of the walls of the coalescing cells; the lining epithelium must be a subsequent formation. Whilst the finest capillaries retain this simple structure, those that are larger acquire the additional coats already described; and arteries and veins, as already stated, especially the smaller ones, appear to be formed in the same manner; indeed, it would seem not unreasonable to presume, that the several gradations of structure seen as permanent conditions in vessels of successively larger calibre, may represent the successive steps by which a vessel, having originally the small size and the simple membrane of a fine capillary, increases in width and acquires the complex tunics of a vein or artery. Further observations, however, are required on this point. Kölliker states, that many vessels which eventually attain a medium size, are originally derived from round cells, which unite in single or double rows and form the primitive simple membranous tube of such vessels, by coalescence of their cavities and walls.

Fig. XCIX.

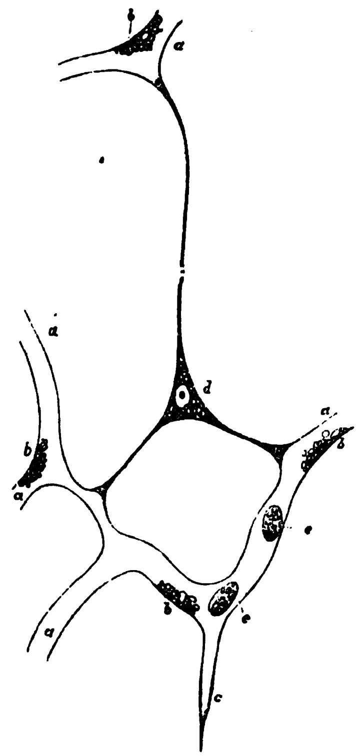


Fig. XCIX.—Capillary Blood Vessels of the Tail of a very Young Frog Larva. Magnified 350 diameters (after Kölliker).

a, capillaries permeable to blood; *b*, granules, attached to the walls of the vessels and concealing nuclei; *c*, hollow prolongation of a capillary, ending in a point: *d*, a branched cell, containing a nucleus and granules, and communicating by three branches with prolongations of capillaries already formed; *e*, blood corpuscles.

The blood-vessels may be said to increase in size and capacity in proportion to the demands made on their service. Thus, as the uterus enlarges in pregnancy, its vessels become enlarged, and when the main artery of a limb is tied, or otherwise permanently obstructed, collateral branches, originally small and insignificant,

* Supplement to Müller's Physiology, by Baly and Kirkes, 1848, p. 104.

augment greatly in size, to afford passage to the increased share of blood which they are required to transmit, and by this admirable adaptation of them to the exigency, the circulation is restored. In such cases, an increase takes place in length, as well as in diameter, and accordingly the vessels very commonly become tortuous.

ABSORBENT OR LYMPHATIC SYSTEM.

Under this head we include not only the vessels specially called lymphatics, together with the glands belonging to them, but also those named lacteal or chyliferous, which form part of the same system, and differ in no respect from the former, save that they not only carry lymph like the rest, but are also employed to take up the chyle from the intestines during the process of digestion and convey it into the blood. An introductory outline of the absorbent system has already been given at page xlvii.

A system of lymphatic vessels is superadded to the sanguiferous in all classes of vertebrated animals, but such is not the case in the invertebrata; in many of these, the sanguiferous vessels convey a colourless or nearly colourless blood, but no additional class of vessels is provided for conveying lymph or chyle, at least none such has hitherto been detected.

Distribution.—In man and those animals in which they are present, the lymphatic vessels are found in nearly all the textures and organs which receive blood; the exceptions are few, and with the progress of discovery may yet possibly disappear.

In the different regions of the body, and in the several internal viscera, the lymphatics are arranged in a superficial and a deep set. The former run underneath the skin or under the membranous coats immediately enveloping the organs in which they are found; the latter usually accompany the deep-seated blood-vessels. The principal lymphatic vessels of a part exceed the veins in number, but fall short of them in size; they also anastomose or intercommunicate much more frequently than the veins alongside of which they run.

Origin.—Lymphatics may arise superficially, *i.e.* immediately underneath free surfaces, both external and internal, as for example those of the skin and mucous membranes, or deeply, in the substance of organs.

Plexiform origin.—When they arise superficially, the lymphatics most generally begin in form of networks or plexuses, out of which single vessels emerge at various points and proceed to enter lymphatic glands or to join larger lymphatic trunks. Such mode of commencement may be termed the *plexiform.* The plexuses for the most part consist of several strata, becoming finer as they approach the surface, in respect both of the calibre of the vessels and the closeness of their reticulation. This is shown in figure c., which is meant to represent the lymphatic plexuses of the skin. But even the most superficial and finest network is composed of vessels which are larger than the sanguiferous capillaries.

The short anastomosing branches of these plexuses are often of very unequal size, even in the same stratum, some being dilated and almost saccular whilst others immediately communicating with these are narrow, so that the network may assume a varicose character. In some situations the plexuses have much the appearance of strata of intercommunicating cellular cavities, and a characteristic example of this appearance is afforded by the intestine of the turtle after its lymphatics have been injected with mercury; these vessels are then seen to emerge from what has all the appearance of a dense stratum of small rounded cells filled with mercury and lying beneath the surface of the mucous coat. This appearance, however, may be regarded as

produced by the short distended branches of a very close lymphatic network, and transitions are accordingly met with between this and the more usual and regular forms.

But whilst the superficial commencement of lymphatics is generally plexiform, the rule is not without exception. The lacteals of the intestinal villi, for example, although they form networks in the larger and broader villi, arise in others by a single vessel beginning with a blind or closed extremity at the free end of the villus, whence it sinks down to join the general plexus of the intestinal membrane.

Fig. C.

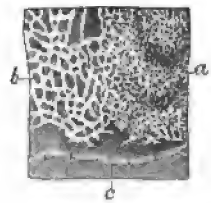


Fig. C.—Lymphatic Vessels of the Skin of the Breast injected (after Breschet).

a, superficial, and *b*, deeper plexus; *c*, a lymphatic vessel, which proceeded to the axillary glands.

Lacunar origin. — When lymphatics arise deeply, their origin may be hidden from view, and the precise mode in which it takes place unknown. There may be cases in which it is still plexiform; but another and doubtless more general mode of origin from the interior of organs, long suspected and often upheld on imperfect evidence, has now been satisfactorily ascertained, which may not inappropriately be termed *lacunar*. In this case the lymphatic vessels proceed from irregular or shapeless spaces in the internal parts of organs; the spaces, that is, which intervene between the several structures of which the organ is composed. Thus, in a gland, they are the spaces which lie between or surround the blood-vessels, secreting tubes or saccules, partitioning or inclosing membranes, and the like. Though shapeless, or at least of no regular form, these anfractuous cavities are limited and defined by a lining of epithelium, agreeing in character with that of the lymphatic vessels. It may be presumed that their opposite sides are in apposition or in near proximity, as in serous membranes, for the lymph deposited in these recesses is not suffered to accumulate, but is drained off by the lymphatic vessels which lead out of them.

The lacunar condition of the lymphatic system at its commencement was shown to exist in the testicle by Ludwig and Tomsa, and has since then been found in the kidney by Ludwig and Zwarykin, in the thymus gland by Frey, in the spleen by Tomsa, in the liver (forming canals which inclose the blood-capillaries) by MacGillivray, and in the salivary glands by Giannuzzi. His has also discovered that the blood-vessels of the brain and spinal cord are surrounded and inclosed by lymph-channels—*perivascular canals*—which follow their course and eventually terminate in ordinary lymphatic vessels; an arrangement that brings to mind an earlier observation of Rusconi, who found that the aorta and mesenteric arteries of the frog and salamander are inclosed in large lymphatic canals. The spaces which so extensively separate the frog's skin from the subjacent muscles, were recognised by the late Professor Johannes Müller as belonging to the lymphatic system, and von Recklinghausen has shown that the subcutaneous lymph spaces of the frog's leg communicate with lymphatic vessels which envelope the blood-vessels of the foot; also that milk injected into these spaces finds its way into the blood. The lymphatic system of man and the higher animals in being thus partly constituted by lacunæ or interstitial receptacles, so far agrees with the sanguiferous system of crustaceans and insects.

It has been sometimes maintained that the lymphatics of glandular organs communicate at their origin with the ducts; but, although it is no uncommon thing for matters artificially injected into the ducts of glands, as, for instance, those of the liver and testicle, to pass into the lymphatics, a careful examination of such cases

leads to the conclusion that the injected material does not find its way from the ducts into the lymphatics by any naturally-existing communication, but by accidental rupture of contiguous branches of the two classes of vessels. It seems probable, also, that the communications often held to exist between the commencing lymphatics, both superficial and deep, and capillary blood vessels, have no better foundation, and that the passage of injection, here also relied on as evidence, is to be accounted for in the same way. A fact mentioned by Kölliker throws light on these alleged communications with sanguiferous capillaries. In investigating the lymphatics of the tadpole's tail with the microscope, that observer not unfrequently noticed that blood corpuscles got into the lymphatics from the small blood-vessels, and he was able to recognise in the living animal the communications by which they passed. At first he looked on these communications as natural, but after repeated and careful investigations, he satisfied himself that they were produced accidentally by contusion or some other injury inflicted on the parts.

Structure.—In structure the lymphatic vessels much resemble the veins, only their coats are thinner, so thin and transparent indeed that the contained fluid can be readily seen through them. When lymphatics have passed out from the commencing plexuses and lacunæ they are found to have three coats. The internal coat is covered with a lining of epithelium, consisting of a single layer of flattened nucleated cells, which in the larger lymphatics have mostly an oblong figure, but in small or commencing vessels are more rounded, with an indented, bluntly serrated, or wavy border, by which the adjacent cells fit to each other, like the epidermic cells of grasses and some other plants (fig. CI.). Beneath the epithelium the inner coat is formed of a layer or layers of longitudinal elastic fibres. The middle coat consists of plain muscular tissue disposed circularly, mixed with finely reticulating elastic fibres taking the same direction. The external coat is composed mainly of white connective tissue with a sparing intermixture of longitudinal elastic fibres, and some longitudinal and oblique bundles of plain muscular tissue. In the thoracic duct there are striated white layers (as in the aorta) beneath the epithelium, between it and the elastic layers of the inner coat; and in the middle coat there is a longitudinal layer of white connective tissue with elastic fibres, immediately within the muscular layer.

Fig. CI.

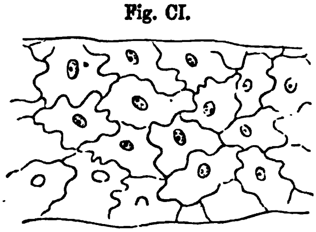


Fig. CI.—Portion of a Lymphatic Vessel showing its peculiar Epithelium. Treated with nitrate of silver. From the Intermuscular Layer of the Intestine of the Guinea Pig (after Auerbach). Magnified 240 diameters.

The commencing lymphatics, whether in plexuses or single (as in the villi), for the most part look like mere channels excavated in the surrounding tissue, without independent coats, and they were regarded as such by various eminent authorities. It has now, however, been ascertained that they invariably have a lining of epithelium formed of the characteristic indented scales (fig. CI.), as in other small lymphatics. This is made apparent by injection of solution of nitrate of silver, which blackens and brings into view the serrated lines of juncture of the flattened cells, whilst the nuclei may be made to appear by means of acetic acid or carmine. But it is not clearly determined whether there is any other coat outside the epithelium, even in cases where the vessels are separable from the adjoining tissue. By the same method of preparation an epithelial lining of similarly

marked character has been shown to exist on the walls of the interstitial lymph spaces or lacunæ of origin.

The lymphatics receive vasa vasorum, which ramify in their outer and middle coats: nerves distributed to them have not yet been discovered, although their probable existence has been inferred on physiological grounds.

Vital properties.—That the lymphatics are endowed with vital contractility is shown by the effect of mechanical irritation applied to the thoracic duct, as well as by the general shrinking and emptying of the lacteal and lymphatic vessels on their exposure to the contact of cold air, in the bodies of animals opened immediately after death.

Valves.—The lymphatic and lacteal vessels are furnished with valves serving the same office as those of the veins, and for the most part constructed after the same fashion. They generally consist of two semi-lunar folds arranged in the same way as in the valves of veins already described, but deviations from the usual structure here and there occur. Thus Mr. Lane has observed some valves in which the planes of the semi-lunar flaps were directed not obliquely but transversely across the vessel, an arrangement calculated to impede the flow of fluid in both directions, but not completely to intercept it in either. In others, described by the same authority, the two folds, placed transversely as before, were coalesced at one end, so as to represent a transverse septum with an incomplete transverse slit. In a third variety, he found the valve formed of a circular fold corresponding with a constriction outside, and probably containing circular contractile fibres capable of completely closing the tube.

Valves are not present in all lymphatics, but where they exist they follow one another at much shorter intervals than those of the veins, and give to the lymphatics, when much distended, a beaded or jointed appearance. Valves are placed at the entrance of the lymphatic trunks into the great veins of the neck. They are wanting in the reticularly-arranged vessels which compose the plexuses of origin already spoken of; so that mercury injected into one of these vessels runs in all directions so as to fill a greater or less extent of the plexus, and passes along the separate vessels which issue from it.

The lymphatics of fish and naked amphibia are, generally speaking, destitute of valves, and may therefore be injected from the trunks; in the turtle a few valves are seen on the larger lacteals which pass along the mesentery, but none on those upon the coats of the intestine; and valves are much less numerous in the lymphatics and lacteals of birds than in those of mammiferous animals.

Orifices.—It was at one time a prevalent opinion among anatomists that the lymphatic and lacteal vessels begin on various surfaces by open mouths, through which extraneous matters are absorbed. This was especially insisted on as regards the commencing lacteals in the intestinal villi. That opinion has been since given up; but quite recently von Recklinghausen has obtained what he considers satisfactory evidence of openings in the lymphatics on the surface of the peritoneum. He stretched the tendinous centre of the diaphragm, excised from a rabbit, over a ring of cork, covered it with a film of milk, and then, watching it with the microscope, saw the milk globules at various points drawn down as if in a vortex, and disappearing. He then found they had passed into the lymphatics of the peritoneal covering of the diaphragm, by small openings, not more than twice the diameter of a blood-corpuscle, over which the peritoneal epithelium was similarly perforated. Observations in confirmation of these have since been made in the Physiological Institute of Leipsic, under the direction of Professor Ludwig, by Dr. Dybkowski, who has found epithe-

lial apertures (answering very nearly to those described by von Recklinghausen) on the dog's pleura, by which the superficial lymphatics open on the surface of the membrane; he also found that fine particles of colouring matter could, under certain conditions, be made to pass from the cavity of the pleura into the lymphatics, and apparently by the openings in question.*

Respecting these observations, however, it must be remarked, that the apertures described do not open upon a surface in contact with extraneous matters, as that of the skin or a mucous membrane, but into a serous cavity; and perhaps they may be explained on the supposition that the peritoneum, pleura, and other serous sacs, are really large lymph-lacunæ, from which lymphatic vessels lead out as emissaries, as in the case of the subcutaneous lymph-spaces of the frog, and the testicular and other lymph-lacunæ constructed on a smaller scale.

Absorbent or *lymphatic glands*, named also *conglobate glands*, and by modern French writers *lymphatic ganglions*, are small solid bodies placed in the course of the lymphatics and lacteals, through which the contents of these vessels have to pass in their progress towards the thoracic or the right lymphatic duct. These bodies are collected in numbers along the course of the great vessels of the neck, also in the thorax and abdomen, especially in the mesentery and alongside the aorta, vena cava inferior, and iliac vessels. A few, usually of small size, are found on the external parts of the head, and considerable groups are situated in the axilla and groin. Some three or four lie on the popliteal vessels, and usually one is placed a little below the knee, but none farther down. In the arm they are found as low as the elbow joint.

Lymphatic vessels may pass through two, three, or even more lymphatic glands in their course, whilst, on the other hand, there are lymphatics which reach the thoracic duct without encountering any gland in their way.

The size of these bodies is very various, some being not much bigger than a hempseed, and others as large or larger than an almond or a kidney-bean. In shape, too, they present differences, but most of them are round or oval.

The lymphatics or lacteals which enter a gland are named inferent or afferent vessels (*vasa inferentia* seu *afferentia*), and those which issue from it efferent vessels (*vasa efferentia*). The afferent vessels, on approaching a gland, divide into many small branches, which enter the gland; the efferent vessels commonly leave the gland in form of small branches, and at a little distance beyond it, or sometimes even before issuing from it, unite into one or more trunks, usually larger in size but fewer in number than those of the afferent vessels.

The internal structure of lymphatic glands has been long a subject of inquiry. Hewson considered that a lymphatic gland essentially consists of a network of finely-divided lymphatic vessels on and between which capillary blood-vessels are ramified; the whole being gathered up and compacted into a comparatively dense mass by connective tissue, which at the surface of the gland forms for it an inclosing capsule. The afferent and efferent vessels are, according to Hewson, continuous with each other within the gland, and the cellular cavities described as intervening between them and serving as the medium of their communication, were held by him to be nothing more than partial dilatations of some branches of the common connecting plexus.

Hewson's view of the constitution of the lymphatic glands was, till

* Berichte der K. Sächs: Gesellsch: der Wissensch: July, 1866, p. 191. In the same publication, p. 247, is an account, by F. Schweigger-Seidel and J. Dogiel, of open communications between the frog's peritoneum and the great lymph-sac (*cisterna magna*) behind it; also founded on observations made in the Physiological Institute of Leipsic.

lately, accepted by most anatomists; but recent researches have shown that the structure of these bodies is more complex. The following account is founded on the descriptions of His and Kölliker.

A lymphatic gland is covered externally with a coat composed of connective tissue, mixed in certain animals, with muscular fibre-cells. This coat or capsule is complete, except at the part where it gives passage to the efferent lymphatics and the larger blood vessels; and this part of the gland, which often presents a depression or fissure, may be named the *hilus* (fig. CII. *a*). The proper substance of the gland consists of two parts, the *cortical*, and within this the *medullary*. The cortical part occupies all the superficial part of the gland, except the hilus, and in the larger glands may attain a thickness of from two to three lines. The medullary portion occupies the centre, and extends to the surface at the hilus. It is best marked in the inwardly seated glands, such as the lumbar and mesenteric, whilst in the subcutaneous glands it is more or less encroached upon by a core of connective tissue, *hilus-stroma* (His), which enters with the larger blood-vessels at the hilus, and surrounds them together with the lymph-vessels, in the centre of the gland, so that the medullary part is reduced to a layer of no great thickness bounding inwardly the cortical part.

Fig. CII.

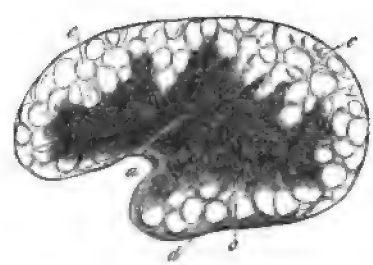


Fig. CII.—Section of a Mesenteric Gland from the Ox, slightly magnified.

a, hilus; *b*, medullary substance; *c*, cortical substance with indistinct alveoli; *d*, capsule (after Kölliker).

Throughout both its cortical and medullary part the gland is pervaded by a trabecular frame-work which incloses and supports the proper glandular substance. The trabeculæ pass inwards from the capsule. They consist, in the ox, chiefly of plain muscular tissue; in man, of connective tissue, sparingly intermixed with muscular fibre-cells. In the cortical part they are mostly lamellar in form, and divide the space into small compartments, *alveoli*, from $\frac{1}{80}$ to $\frac{1}{24}$ of an inch wide, which communicate laterally with each other through openings in the imperfect partitions between them (fig. CIII. A). On reaching the medullary part the trabeculæ take the form of flattened bands or cords, and by their conjunction and reticulation form a freely intercommunicating meshwork throughout the interior. (In the figures they are represented mostly as cut across.) In these alveoles and meshes is included the proper *glandular substance*, which appears as a tolerably firm pulp, or parenchyma. In the alveoli of the cortical part this forms rounded nodules (fig. CIII, A *d*); in the trabecular meshes of the medullary part it takes the shape of rounded cords joining in a corresponding network (figs. CIII. B *d*; CIV. *a a*); and as the containing meshes communicate, so the contained gland-pulp is continuous throughout. But both in the cortical alveoles and the medullary trabecular meshes, a narrow space (left white in the figs. CIII. *l*; CIV., CV. *b*) is left all round the gland-pulp, between it and the alveolar partitions and trabecular bands, like what would be left had the pulp shrunk away from the inside of a mould in which it had been cast. This space is both a receptacle and a channel of passage for the lymph that goes through the gland; it is the *lymph-sinus*

(His), or the *lymph-channel*. It is traversed by retiform connective tissue (fig. CV. *c c*), in which the nuclei of the spindle-shaped or ramified cells are mostly apparent, and is filled with fluid lymph, containing many lymph-corpuscles, which may be washed out from sections of the gland with a hair pencil, so as to show the sinus, while the firmer gland-pulp, which the sinus surrounds, keeps its place. The latter, the proper glandular substance, is also pervaded and supported by retiform tissue, mostly non-nucleated (fig. CV. *a*), communicating with that of the surrounding lymph-sinus, but marked off from it by somewhat closer reticulation at their mutual boundary, not so close, however, as to prevent fluids, or even solid corpuscles, from passing from the one to the other. This glandular pulp is made up of densely-packed lymph-corpuscles, occupying the interstices of

Fig. CIII.

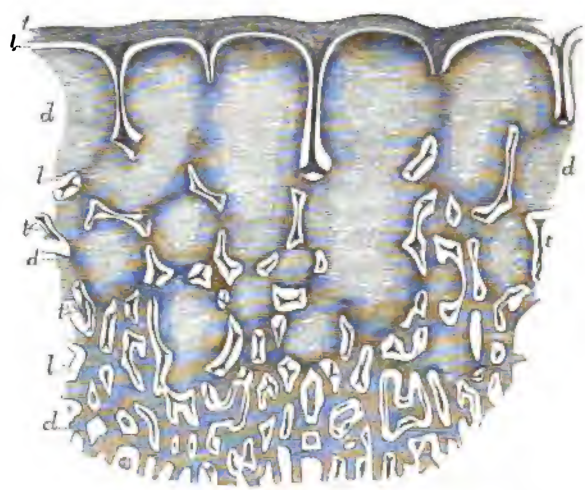


Fig. CIII.—Section of a Mesenteric Gland of the Ox (magnified 12 diameters).

The section includes a portion of the cortical part, A, in its whole depth, and a smaller portion of the adjoining medullary part, B; *c*, *c*, outer coat or capsule sending partitions into the cortical part to form alveoli, and trabeculæ, *t t*, which are seen mostly cut across; *d d*, the glandular substance forming nodules in the cortical part, A, and reticulating cords in the medullary part, B; *l*, *l*, lymph-sinus or lymph channel, left white (after His).

its supporting retiform tissue, and is traversed by an abundant network of capillary blood-vessels, which runs throughout the proper glandular pulp, both cortical and medullary, but does not pass into the surrounding lymph-sinus. Arteries enter and veins leave the gland at the hilus, surrounded, in some glands, as already said, with a dense inclosure of connective tissue. The arterial branches go in great part directly to the glandular substance, but partly also to the trabeculæ. The former end in the glandular capillary network above-mentioned, from which the veins begin, and tend to the hilus alongside the arteries. The branches to the trabeculæ run upon these bands, and are in part conducted to the coat of the gland to be there distributed; some of them in an indirect way reach the glandular substance. The blood-vessels of the gland-pulp are supported by its pervading retiform tissue, which is not only connected to them, but forms an additional or

adventitious coat round their small branches, and even on some of the capillaries (page clxxix).

Fig. CIV.

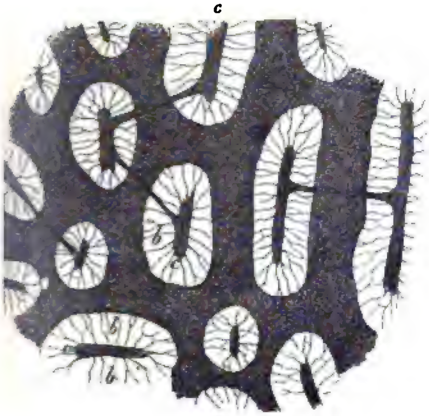


Fig. CV.

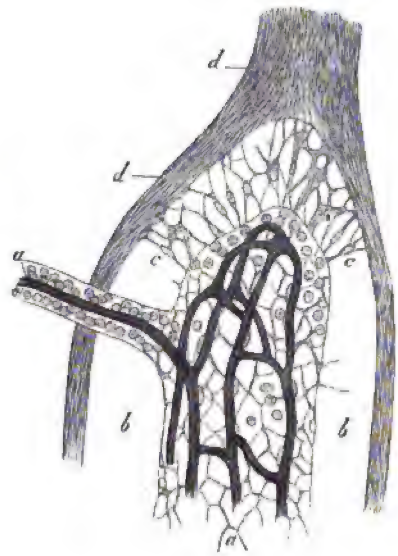


Fig. CIV.—Section of Medullary Substance of an Inguinal Gland of the Ox (magnified 90 diameters.)

a, *a*, glandular substance or pulp forming rounded cords joining in a continuous net (dark in the figure); *c*, *c*, trabeculæ; the space, *b*, *b*, between these and the glandular substance is the lymph-sinus, washed clear of corpuscles and traversed by filaments of retiform connective tissue (after Kölliker).

Fig. CV.—A very small portion of the Medullary Substance from a Mesenteric Gland of the Ox (magnified 300 diameters).

d, *d*, trabeculæ; *a*, part of a cord of glandular substance from which all but a few of the lymph corpuscles have been washed out to show its supporting meshwork of retiform tissue and its capillary bloodvessels (which have been injected, and are dark in the figure); *b*, *b*, lymph-sinus, of which the retiform tissue is represented only at *c*, *c* (after Kölliker).

As to the lymphatics of the gland, it seems now to be tolerably well made out, that the afferent vessels, after branching out upon and in the tissue of the capsule, send their finer branches through it to open into the lymph-sinuses of the cortical alveoli, and that the efferent lymphatics begin by fine branches leading from the lymph-sinuses of the medullary part, and forming at the hilus a dense plexus of tortuous and varicose-looking vessels, from which branches proceed to join the larger efferent trunks. The lymph-sinus, therefore, forms a channel for the passage of the lymph, interposed between the afferent and efferent lymphatics, communicating with both, and maintaining the continuity of the lymph stream. The afferent and efferent vessels, where they open into the lymph-sinus, lay aside all their coats, except the epithelium, and the sinus is lined throughout its whole extent with a similar epithelium, consisting, as in the commencing lymph-lacunæ, of a single layer of flattened cells.

It is not unreasonable to presume that in the proper glandular substance, there is a continual production of lymph-corpuscles, most probably by fissiparous multiplication, which pass into the lymph sinus, and that fresh corpuscles are thus added to the lymph as it passes through a gland; and this view is supported by the fact, that the corpuscles are found to be more abundant in the lymph or chyle after it has passed through the glands (see page l.). It has been alleged, moreover, that the lymph, after passing the glands, is richer in fibrin, and therefore coagulates more firmly. In any case it is plain that the numerous blood capillaries distributed in a gland, must bring the blood into near relation with the elements of the lymph, and the latter fluid, as it must move very slowly through the relatively wide space within the gland, is thus placed in a most favourable condition for some not improbable interchange of material with the blood.

Termination.—The absorbent system discharges its contents into the veins at two points, namely, at the junction of the subclavian and internal jugular veins of the left side by the thoracic duct, and in the corresponding part of the veins of the right side by the right lymphatic trunk. The openings, as already remarked, are guarded by valves. It sometimes happens that the thoracic duct divides, near its termination, into two or three short branches, which open separately, but near each other; more rarely, a branch opens into the vena azygos—indeed the main vessel has been seen terminating in that vein. Again, it is not uncommon for larger branches, which usually join the thoracic duct, to open independently in the vicinity of the main termination; and this is more apt to happen with the branches which usually unite to form the right lymphatic trunk. By such variations the terminations in the great veins are multiplied, but still they are confined in man to the region of the neck; in birds, reptiles, and fish, on the other hand, communications take place between the lymphatics of the pelvis, posterior extremities and tail, and the sciatic or other considerable veins of the abdomen or pelvis.

The alleged terminations of lymphatics in various veins of the abdomen, described by Lippi as occurring in man and mammalia, have not been met with by those who have since been most engaged in the prosecution of this department of anatomical research, and accordingly his observations have generally been either rejected as erroneous, or held to refer to deviations from the normal condition.* But, while such (extra-glandular) terminations in other veins than those of the neck have not been generally admitted, several anatomists of much authority have maintained that the lacteals and lymphatics open naturally into veins within the lymphatic glands. This latter opinion which has been strenuously advocated by Fohmann in particular, is based on a fact well known to every one conversant with the injection of the vessels in question, namely, that the quicksilver usually employed for that purpose, when it has entered a gland by the inferent lymphatics, is apt to pass into branches of veins within the gland, and thus finds its way into the large venous trunks in the neighbourhood, in place of issuing by the efferent lymphatic vessels. But, although it, of course, cannot be doubted that, in such cases, the mercury gets from the lymphatics into the veins, no one has yet been able to perceive the precise mode in which the transmission takes place, and, looking to the circumstances in which it chiefly occurs, it seems to be more probably owing to rupture of contiguous lymphatics and veins within the glands, than to a natural communication between the two classes of vessels in that situation.

Lymphatic hearts.—Müller and Panizza, nearly about the same time, but independently of each other, discovered that the lymphatic system of reptiles is furnished, at its principal terminations in the venous system, with pulsatile muscular sacs,

* In a communication inserted in Müller's Archiv. for 1848, p. 173, Dr. Nuhn, of Heidelberg, affirms the regular existence of these abdominal terminations, and refers to three instances which he met with himself. In two of these, the lymphatics opened into the renal veins, and in the other into the vena cava.

which serve to discharge the lymph into the veins. These organs, which are named lymph-hearts, have now been found in all the different orders of reptiles. In frogs and toads two pairs have been discovered, a posterior pair, situated in the sciatic region, which pour their lymph into a branch of the sciatic or of some other neighbouring vein, and an anterior more deeply-seated pair, placed over the transverse process of the third vertebra, and opening into a branch of the jugular vein. The parietes of these sacs are thin and transparent, but contain muscular fibres of the striated kind, freely ramifying, decussating in different layers, as in the blood-heart. In their pulsations they are quite independent of the latter organ, and are not even synchronous with each other. In salamanders, lizards, serpents, tortoises, and turtles, only a posterior pair have been discovered, which, however, agree in all essential points with those of the frog. In the goose, and in other species of birds belonging to different orders, Panizza discovered a pair of lymph-sacs opening into the sacral veins, and Stannius has since found that these sacs have striated muscular fibres in their parietes; but, although this observer, in some cases, exposed them in the living bird, he was not able to discover any pulsation or spontaneous movement in them. Nerve-fibres, both dark bordered and pale, have been observed in the lymph-hearts of the frog, and also nerve-cells in those of the common tortoise. (Waldeyer.)

Development of lymphatic vessels.—Kölliker has observed the formation of lymphatics from ramified cells in the tails of young salamander-larvæ. He states that the process takes place nearly in the same manner as in the case of sanguiferous capillaries; the only notable difference being, that whilst the growing lymphatics join the ramified cells, and thus extend themselves, their branches very rarely anastomose or become connected by communicating arches. The soundness of his conclusions has, however, been called in question and the subject requires further elucidation. New-formed lymphatics have been injected in adhesions between inflamed serous membranes.

SEROUS MEMBRANES.

The serous membranes are so named from the apparent nature of the fluid with which their surface is moistened. They line cavities of the body which have no outlet, and the chief examples of them are, the peritonæum, the largest of all, lining the cavity of the abdomen; the two pleuræ and pericardium in the chest; the arachnoid membrane in the cranium and vertebral canal; and the tunica vaginalis surrounding each of the testicles within the scrotum.

Form and arrangement.—In all these cases the serous membrane has the form of a closed sac, one part of which is applied to the walls of the cavity which it lines, the *parietal* portion; whilst the other is reflected over the surface of the organ or organs contained in the cavity, and is therefore named the *reflected* or *visceral* portion of the membrane. Hence the viscera in such cavities are not contained within the sac of the serous membrane, but are really placed behind or outside of it; merely pushing inwards, as it were, the part of the membrane which immediately covers them, some organs receiving in this way a complete, and others but a partial and sometimes very scanty investment.

In passing from one part to another, the membrane frequently forms folds which in general receive the appellation of ligaments, as, for example, the folds of peritonæum passing between the liver and the parietes of the abdomen, but which are sometimes designated by special names, as in the instances of the mesentery, meso-colon, and omentum.

The peritonæum, in the female sex, is an exception to the rule that serous membranes are perfectly closed sacs, inasmuch as it has two openings by which the Fallopian tubes communicate with its cavity.

A serous membrane sometimes lines a fibrous membrane, as where the arachnoid lines the dura mater, or where the serous layer of the peri-

cardium adheres to its outer or fibrous part. Such a combination is often named a *fibro-serous* membrane.

The inner surface of a serous membrane is free, smooth, and polished; and, as would occur with an empty bladder, the inner surface of one part of the sac is applied to the corresponding surface of some other part; a small quantity of fluid, usually not more than merely moistens the contiguous surfaces, being interposed. The parts situated in a cavity lined by serous membrane can thus glide easily against its parietes or upon each other, and their motion is rendered smoother by the lubricating fluid.

The outer surface most commonly adheres to the parts which it lines or covers, the connection being effected by means of areolar tissue, named therefore "subserous," which, when the membrane is detached, gives to its outer and previously adherent surface a flocculent aspect. The degree of firmness of the connection is very various: in some parts, the membrane can scarce be separated; in others, its attachment is so lax as to permit of easy displacement. The latter is the case in the neighbourhood of the openings through which abdominal herniæ pass, and accordingly when such protrusions of the viscera happen to take place, they usually push the peritonæum before them in form of a hernial sac.

The visceral portion of the arachnoid membrane is in some measure an exception to the rule of the outer surface being everywhere adherent; for in the greater part of its extent, it is thrown loosely round the parts which it covers, a few fine fibrous bands being the sole bond of connection; and a quantity of pellucid fluid is interposed, especially in the vertebral canal and base of the cranium, between the arachnoid and the pia mater, which is the membrane immediately investing the brain and spinal cord.

Structure and properties.—Serous membranes are thin and transparent, so that the colour of subjacent parts shines through them. They are tolerably strong, with a moderate degree of extensibility and elasticity. They consist of, 1st, a simple layer of scaly *epithelium* already described and figured (fig. xx.), which, however, is in part ciliated on the serous membrane lining the ventricles of the brain and central canal of the spinal cord. 2ndly, the *fibrous layer*. This consists of fine but dense areolar connective tissue, which is, as usual, made up of bundles of white filaments mixed with fine elastic fibres; the former, when there are two or more strata, take a different direction in the different planes; the latter unite into a network, and, in many serous membranes, as remarked by Henle, are principally collected into a reticular layer at the surface, immediately beneath the epithelium. The constituent connective tissue of the serous membrane is of course continuous with the usually more lax *subserous areolar tissue* connecting the membrane to the subjacent parts. Where the arachnoid membrane lines the dura mater, and possibly also in some other cases, the fibrous layer usually belonging to the serous membrane is wanting, its place being supplied by the fibrous membrane beneath, on which the epithelium is immediately applied.

Blood-vessels ending in a capillary network with comparatively wide meshes pervade the subserous tissue and the tissue of the serous membrane. Plexuses of lymphatics also exist in the subserous tissue, but not under every part of the membrane; in the costal pleura, for example, the lymphatics are confined to the parts which cover the intercostal and sterno-costal muscles. When present the lymphatics extend in form of fine superficial plexuses through the fibrous layer of the membrane to its surface, immediately beneath the epithelium (Dybkowski), and may then open into the serous

cavity by cognizable apertures, as already stated. Fine nervous fibres, with nerve-cells in some places, have been described by several anatomists, in or immediately beneath the serous membranes of various regions; nevertheless it would seem, that when in a healthy condition these membranes possess little or no sensibility; they are altogether devoid of vital contractility.

Fluid.—The internal surface of serous cavities is moistened and lubricated with a transparent and nearly colourless fluid, which in health exists only in a very small quantity. This fluid, which is doubtless derived from the blood-vessels of the membrane, has been commonly represented as similar in constitution to the serum of the blood. But it was long since remarked by Hewson (and a similar opinion seems to have been held by Haller and Monro), that the fluid obtained from the serous cavities of recently-killed animals coagulates spontaneously, and thus resembles the lymph of the lymphatic vessels, and, we may add, the liquor sanguinis or plasma of the blood, the coagulation being, of course, due to the presence of fibrin, or of its two constituents fibrinogen and globulin. Hewson, who regarded the fluid as lymph, found that the coagulability diminished as the quantity increased. In confirmation of Hewson's statement, I may mention that I have always found the fluid obtained from the peritoneal cavity of rabbits to coagulate spontaneously in a greater or less degree. Hewson made his observations on the fluid of the peritonæum, pleura, and pericardium, in various animals, viz., bullocks, dogs, geese, and rabbits.*

When the fluid gathers in unusual quantity as in dropsies, it rarely coagulates spontaneously on being let out; but will often yield a coagulum on the addition of globulin as already stated (page xxxviii.). From this it may be inferred that fibrinogen is present, but not the globulin (fibrino-plastin) requisite to generate fibrin.

The identity in character of the fluid of serous cavities and the lymph plasma is, it need scarcely be remarked, in keeping with the notion of their being great lymph-spaces in open connection with lymphatic vessels. But this view is quite reconcilable with the mechanical purpose commonly ascribed to these membranes, of lubricating and facilitating the movement of mutually opposed surfaces.

When a serous membrane is inflamed, it has a great tendency to throw out coagulable lymph (or fibrin) and serum, the two constituents of the blood-plasma, the former chiefly adhering to the inner surface of the membrane, whilst the latter gathers in its cavity. The coagulable lymph spread over the surface, in form of a "false membrane," as it is called, or agglutinating the opposed surfaces of the serous sac and causing adhesion, becomes pervaded by blood-vessels, and in process of time converted into areolar tissue.

Breaches of continuity in these membranes are readily repaired, and the new-formed portion acquires all the characters of the original tissue.

SYNOVIAL MEMBRANES.

Resembling serous membranes in general form and structure, the synovial membranes are distinguished by the nature of the secretion which lubricates their surface, for this is a viscid glairy fluid resembling the white of an egg, and thence named *synovia*.

These membranes line the cavities of joints, and are interposed between moving parts in certain other situations; being in all cases intended to lessen friction, and thereby facilitate motion. They are composed of a scaly epithelium, which may consist of several strata, and a layer of dense areolar tissue pervaded by vessels and attached by tissue of the same kind to the parts beneath.

The different synovial membranes of the body are referred to three classes, viz., *articular*, *vesicular*, and *vaginal*.

1. *Articular synovial membranes*, or *Synovial capsules of joints*. These

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line and by their synovial secretion lubricate the cavities of the diarthrodial articulations, that is, those articulations in which the opposed surfaces glide on each other. In these cases the membrane may be readily seen covering internally the surface of the capsular or other ligaments which bound the cavity of the joint, and affording also an investment to the tendons or ligaments which happen to pass through the articular cavity, as in the instance of the long tendon of the biceps muscle in the shoulder-joint. On approaching the articular cartilages the membrane passes over their margins, and becoming much more firmly adherent, terminates after advancing but a little way on their surface. This, as already explained (page lxxxiii.), is the condition in the adult, but in the fœtus the membrane, closely adhering, is continued over the whole surface of the cartilage, so that it would seem to become obliterated or absorbed in consequence of pressure or friction when the joint comes to be exercised. The blood-vessels in and immediately underneath the membrane are sufficiently manifest in most parts of the joint. They advance but a little way upon the cartilages, forming a vascular zone round the margin of each, named "circulus articuli vasculosus," in which they end by loops of vessels dilated at the bent part greatly beyond the diameter of ordinary capillaries. In the fœtus, according to Mr. Toynbee, these vessels, like the membrane itself, advance further upon the surface of the cartilage.

In several of the joints, folds of the synovial membrane, often containing more or less fat, pass across the cavity; these have been called synovial or mucous ligaments. Other processes of the membrane simply project into the cavity at various points. These are very generally cleft into fringes at their free border, upon which their blood-vessels, which are numerous, are densely distributed. They often contain fat, and then, when of tolerable size, are sufficiently obvious; but many of them are very small and inconspicuous. The fringed vascular folds of the synovial membrane were described, by Dr. Clopton Havers (1691), under the name of the *mucilaginous glands*, and he regarded them as an apparatus for secreting synovia. Subsequent anatomists, while admitting that, as so many extensions of the secreting membrane, these folds must contribute to increase the secretion, have, for the most part, denied them the special character of glands, considering them rather in the light of a mechanical provision for occupying spaces which would otherwise be left void in the motion of the joints, and this view is no doubt right as regards the larger, fat-inclosing folds. The smaller and less obvious fringes have, however, been found, on investigation by Mr. Rainey, to be most probably secreting organs as originally supposed by Havers. Mr. Rainey * has found that the processes in question exist in the bursal and vaginal synovial membranes as well as in those of joints, wherever, in short, synovia is secreted. He states that their blood-vessels have a peculiar convoluted arrangement, differing from that of the vessels of fat, and that the epithelium covering them, "besides inclosing separately each packet of convoluted vessels, sends off from each tubular sheath secondary processes of various shapes, into which no blood-vessels enter." Kölliker, who has since taken up the inquiry, also finds that fringed membranes exist in all joints and synovial sheaths, as well as in most synovial bursæ, and that they consist of vascular tufts of the synovial membrane, covered by epithelium, and now and then containing fat-cells and more rarely isolated cartilage cells. He also observed the curious "non-vascular secondary processes," described by Mr. Rainey, the larger of which, he says, consist of fibres of areolar tissue in the centre, sometimes containing cartilage cells, and a covering of irregularly thickened epithelium.

2. *Vesicular* or *Bursal synovial membranes, Synovial bursæ, Bursæ mucosæ.*—In these the membrane has the form of a simple sac, interposed, so as to prevent friction, between two surfaces which move upon each other. The sy-

* Proceedings of the Royal Society; May 7th, 1846.

novial sac in such cases is flattened and has its two opposite sides in apposition by their inner surface which is free and lubricated with synovia, whilst the outer surface is attached by areolar tissue to the moving parts between which the sac is placed. As in the case of articular synovial membranes, the bursal membrane on the rubbing surfaces may be, at parts, obliterated.

In point of situation the bursæ may be either deep-seated or subcutaneous. The former are for the most part placed between a muscle or its tendon and a bone or the exterior of a joint, less commonly between two muscles or tendons: certain of the bursæ situated in the neighbourhood of joints not unfrequently open into them. The subcutaneous bursæ lie immediately under the skin, and are found in various regions of the body interposed between the skin and some firm prominence beneath it. The large bursa situated over the patella is a well-known example of this class, but similar, though smaller bursæ are found also over the olecranon, the malleoli, the knuckles, and various other prominent parts. It must, however, be observed, that, among these subcutaneous bursæ, some are reckoned which do not always present the characters of true synovial sacs, but look more like mere recesses in the subcutaneous areolar tissue, larger and more defined than the neighbouring areolæ, but still not bounded by an evident synovial membrane. These have been looked on as examples of less developed structure, forming a transition between the areolar tissue and perfect synovial membrane.

3. *Vaginal Synovial membranes* or *Synovial sheaths.*—These are intended to facilitate the motion of tendons as they glide in the fibrous sheaths which bind them down against the bones in various situations. The best-marked examples of such fibrous sheaths are to be seen in the hand and foot, and especially on the palmar aspect of the digital phalanges, where they confine the long tendons of the flexor muscles. In such instances one part of the synovial membrane forms a lining to the osseo-fibrous tube in which the tendon runs, and another part is reflected at each end upon the tendon, and affords it a close investment. The space between the parietal and reflected portions of the membrane is lubricated with synovia and crossed obliquely by one or more folds or duplications of the membrane, in some parts inclosing elastic tissue. These are named "frœna," and pass from one part of the membrane to the other.

Synovia.—As already stated, this is a viscid transparent fluid; it has a yellowish or faintly reddish tint, and a slightly saline taste. According to Frerichs, the synovia of the ox consists of 94·85 water, 0·56 mucous and epithelium, 0·07 fat, 3·51 albumen and extractive matter, and 0·99 salts. If a drop of synovial fluid is examined microscopically, it is found to contain (in addition to fat-molecules and epithelium cells) small, granular corpuscles, bearing a close resemblance to the pale corpuscles of the blood. It is doubtful whether these bodies have a special nature and purpose, or whether they are merely transitory forms of epithelium particles.

MUCOUS MEMBRANES.

These membranes, unlike the serous, line internal passages, and other cavities which open on the surface of the body, as well as various recesses, sinuses, gland-ducts and receptacles of secretion, which open into such passages. They are habitually subject to the contact of foreign substances introduced into the body, such as air and aliment, or of various secreted or excreted matters, and hence their surface is coated over and protected by mucus, a fluid of a more consistent and tenacious character than that which moistens the serous membranes.

The mucous membranes of several different or even distant parts are continuous, and, with certain unimportant reservations, to be afterwards explained, they may all be reduced to two great divisions, namely, the *gastro-pulmonary* and *genito-urinary*. The former covers the inside of the alimentary and air passages as well as the less considerable cavities communicating with them. It may be described as commencing at the edges of the lips and nostrils where it is continuous with the skin, and proceeding through the nose and mouth to the throat, whence it is continued throughout the whole length of the alimentary canal to the termination of the intestine, there again meeting the skin, and also along the windpipe and its numerous divisions as far as the air cells of the lungs, to which it affords a lining. From the nose the membrane may be said to be prolonged into the lachrymal passages, extending up the nasal duct into the lachrymal sac and along the lachrymal canals until, under the name of the conjunctival membrane, it spreads over the fore part of the eyeball and inside of the eyelids, on the edges of which it encounters the skin. Other offsets from the nasal part of the membrane line the frontal, ethmoidal, sphenoidal and maxillary sinuses, and from the upper part of the pharynx a prolongation extends on each side along the Eustachian tube to line that passage and the tympanum of the ear. Besides these there are offsets from the alimentary membranes to line the lachrymal, salivary, pancreatic, and biliary ducts, and the gall-bladder. The *genito-urinary* membrane invests the inside of the urinary bladder and the whole tract of the urine in both sexes, from the interior of the kidneys to the orifice of the urethra, also the seminal ducts and vesicles in the male, and the vagina, uterus, and Fallopian tubes in the female.

The mucous membranes lining the ducts of the mammary glands, being unconnected with either of the above-mentioned great tracts, have sometimes been enumerated as a third division, and the number might of course be multiplied, were we separately to reckon the membranes prolonged from the skin into the ducts of the numerous little glands which open on the surface of the body.

The mucous membranes are attached by one surface to the parts which they line or cover by means of areolar tissue, named "submucous," which differs greatly in quantity as well as in consistency in different parts. The connection is in some cases close and firm, as in the cavity of the nose and its adjoining sinuses; in other instances, especially in cavities subject to frequent variation in capacity, like the gullet and stomach, it is lax and allows of some degree of shifting of the connected surfaces. In such cases as the last-mentioned the mucous membrane is accordingly thrown into folds when the cavity is narrowed by contraction of the exterior coats of the organ, and of course these folds, or *rugæ*, as they are named, are effaced by distension. But in certain parts the mucous membrane forms permanent folds, not capable of being thus effaced, which project conspicuously into the cavity which it lines. The best-marked example of these is presented by the *valvulæ conniventes* seen in the small intestine. These, as is more fully described in the special anatomy of the intestines, are crescent-shaped duplicatures of the membrane, with connecting areolar tissue between their laminæ, which are placed transversely and follow one another at very short intervals along a great part of the intestinal tract. The chief purpose of the valvulæ conniventes is doubtless to increase the surface of the absorbing mucous membrane within the cavity, and it has also been supposed that they serve mechanically to delay the alimentary mass in its progress downwards. A mechanical office has also been as-

signed to a series of oblique folds of a similar permanent kind, though on a smaller scale, which exist within the cystic duct.

Physical properties.—In most situations the mucous membranes are nearly opaque or but slightly translucent. They possess no great degree of tenacity and but little elasticity, and hence are readily torn by a moderate force. As to colour, they cannot be said intrinsically to have any, and when perfectly deprived of blood they accordingly appear white or at most somewhat grey. The redness which they commonly exhibit during life, and retain in greater or less degree in various parts after death, is due to the blood contained in their vessels, although it is true that after decomposition has set in, the red matter of the blood, becoming dissolved, transudes through the coats of the vessels, and gives a general red tinge to the rest of the tissue. The degree of redness exhibited by the mucous membranes after death is greater in the fœtus and infant than in the adult. It is greater too in certain situations; thus, of the different parts of the alimentary canal, it is most marked in the stomach, pharynx, and rectum. Again, the intensity of the tint, as well as its extent, is influenced by circumstances accompanying or immediately preceding death. Thus the state of inflammation, or the local application of stimuli to the membrane, such as irritant poisons, or even food in the stomach, is apt to produce increased redness; and all the mucous membranes are liable to be congested with blood and suffused with redness when death is immediately preceded by obstruction to the circulation, as in cases of asphyxia, and in many diseases of the heart.

Structure.—A mucous membrane is composed of the *corium* and *epithelium*. The *epithelium* covers the surface, and has already been described (p. iii., *et sqq.*). The membrane which remains after removal of the epithelium is named the *corium*, as in the analogous instance of the true skin. The corium may be said to consist of a *fibro-vascular layer*, of variable thickness, bounded superficially or next the epithelium by an extremely fine transparent lamella, named *basement membrane* by Bowman, and *primary membrane*, *limitary membrane*, and *membrana propria* by others who have described it. It must be explained, however, that these two constituents of the corium cannot in all situations be separated from each other, nor indeed can the presence of both be proved by actual demonstration in all parts of the mucous membranes.

The *basement membrane* is best seen in parts where the mucous membrane is raised into villous processes or where it forms secreting crypts or minute glandular recesses, such as those which abound in the stomach and intestinal canal. On teasing out a portion of the gastric or intestinal mucous membrane under the microscope, some of the tubular glands are here and there discovered which are tolerably well cleared from the surrounding tissue, and their parietes are seen to be formed of a thin pellucid film, which is detached from the adjoining fibro-vascular layer, the epithelium perhaps still remaining in the inside of the tube or having escaped, as the case may be. The fine film referred to is the basement membrane. It may by careful search be seen too on the part of the corium situated between the orifices of the glands, and on the villi, when the epithelium is detached, although it cannot be there separated from the vascular layer. In these parts it manifestly forms a superficial boundary to the corium, passing continuously over its eminences and into its recesses, defining its surface, and supporting the epithelium. In other parts where villi and tubular glands are wanting, and especially where the mucous membrane, more

simply arranged, presents an even surface, as in the tympanum and nasal sinuses, the basement membrane is absent, at least not demonstrated. In such situations it may possibly have originally existed as a constituent of the corium, and have been obliterated or rendered inconspicuous in consequence of subsequent modifications.

The basement membrane, as already said, forms the peripheral boundary of the corium; it is in immediate connection with the epithelium. By its under surface it more or less closely adjoins the fibro-vascular layer. The vessels of the latter advance close up to the basement membrane, but nowhere penetrate it; the delicate film of which it consists is indeed wholly extra-vascular. In structure the membrane in question seems perfectly homogeneous, but marks resembling the nuclei of epithelium cells are sometimes seen disposed evenly over its surface, and some observers, considering these as forming an integrant part of the membrane, have looked on them as so many reproductive centres from which new epithelium particles are generated. Mr. Bowman, on the other hand, considers these objects as nuclei belonging to the undermost and as it were nascent epithelium cells, which have remained adherent to the really simple basement membrane.

The *fibro-vascular layer* of the corium is composed of vessels both sanguiferous and lymphatic, with fibres of connective tissue, and, in many parts, of non-striated muscular tissue, variously disposed. The nerves also which belong to the mucous membrane are distributed in this part of its structure.

The vessels exist universally in mucous membranes, except in that which covers the anterior surface of the cornea; there the epithelium and basement membrane are present, but, in the adult, no vessels except at the border. Elsewhere the branches of the arteries and veins, dividing in the submucous tissue, send smaller branches into the corium, which at length form a network of capillaries in the fibro-vascular layer. This capillary network lies immediately beneath the epithelium, or the basement membrane when this is present, advancing with that membrane into the villi and papillæ to be presently described, and surrounding the tubes and other glandular recesses, into which it is hollowed. The lymphatics also form networks, which communicate with plexuses of larger vessels in the submucous tissue; their arrangement generally, as well as in the villi, has been already noticed.

The fibres of connective tissue which enter into the formation of the corium are both the white and the elastic. The former are arranged in interlacing bundles, the elastic commonly in networks; but the amount of both is very different in different parts. In some situations, as in the gullet, windpipe, bladder, and vagina, the connective tissue is abundant, and extends throughout the whole thickness of the fibro-vascular layer, forming a continuous and tolerably compact web, and rendering the mucous membrane of those parts comparatively stout and tough. In the stomach and intestines, on the other hand, where the membrane is more complex, and at the same time weaker in structure, the elastic fibres are wanting and the white connective tissue is in small proportion; its principal bundles follow and support the blood-vessels, deserting, however, their finer and finest branches which lie next the basement membrane; and accordingly there exists, for some depth below this membrane, a stratum of the corium in which very few if any filaments of the common areolar tissue are seen. In this stratum of the gastro-enteric mucous membrane, the tubular glands with their lining epithelium are set, and between and around them the numerous sanguiferous capillaries and lymphatic vessels are distributed; but the sub-

stance of the membrane in which these parts lie is constructed of the variety of connective tissue known as cytogenous or retiform (p. lxxix, fig. XXXVIII.), which is formed of ramified and reticularly connected corpuscles, with or without nuclei persistent at the points whence the branches divaricate; and in the meshes of this tissue is contained a profusion of granular bodies having all the characters of pale blood- or lymph-corpuscles. This structure (fig. CVI.), which prevails in the mucous membrane of the stomach and intestines, both large and small, is sometimes named *lymphoid tissue* from its resemblance to the interior tissue of the lymphatic glands and of other bodies belonging to or supposed to belong to the lymphatic system, and especially those known as the solitary and agminated glands of the alimentary mucous membrane. The tissue forming the last-named bodies, indeed, is often continuous with the lymphoid tissue in their vicinity. The deepest layer of the alimentary mucous membrane, from the commencement of the œsophagus downwards, is formed throughout by non-striated muscular tissue, and is named *muscularis mucosæ*. This lies next to the submucous tissue, and consists of bundles running in many parts both longitudinally and circularly, in others in one of these directions only. Prolongations from it pass up between the glands to be distributed in the villi.

Fig. CVI.

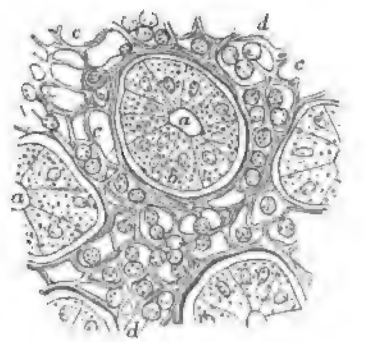


Fig. CVI.—LYMPHOID OR RETIFORM TISSUE OF THE INTESTINAL MUCOUS MEMBRANE OF THE SHEEP (from Frey). MAGNIFIED 400 DIAMETERS.

Cross section of a small fragment of the mucous membrane, including one entire crypt of Lierberkühn and parts of several others: *a*, cavity of the tubular glands or crypts; *b*, one of the lining epithelial cells; *c*, the lymphoid or retiform spaces, of which some are empty, and others occupied by lymph-cells as at *d*.

The free surface of the mucous membranes is in some parts plain, but in others is beset with little eminences named papillæ and villi. The *papillæ* are best seen on the tongue; they are small processes of the corium, mostly of a conical or cylindrical figure, containing blood-vessels and nerves, and covered with epithelium. Some are small and simple, others larger and compound or cleft into secondary papillæ. They serve various purposes; some of them no doubt minister to the senses of taste and touch, many appear to have chiefly a mechanical office, while others would seem intended to give greater extension to the surface of the corium for the production of a thick coating of epithelium. The *villi* are most fully developed on the mucous coat of the small intestines. Being set close together like the pile or nap of cloth, they give to the parts of the membrane which they cover the aspect usually denominated "villous." They are in reality little elevations or processes of the superficial part of the corium, covered with epithelium, and containing blood-vessels and lacteals, which are thus favourably disposed for absorbing nutrient matters from the intestine. The more detailed description of the papillæ and villi belongs to the special anatomy of the parts where they occur.

In some few portions of the mucous membrane the surface is marked with fine ridges which intersect each other in a reticular manner, and thus

inclose larger and smaller polygonal pits or recesses. This peculiar character of the surface of the membrane, which might be called "alveolar," is seen very distinctly in the gall-bladder, and on a finer scale in the vesiculæ seminales; still more minute alveolar recesses with intervening ridges may be discovered with a lens on the mucous membrane of the stomach (fig. CVII.).

Fig. CVII.

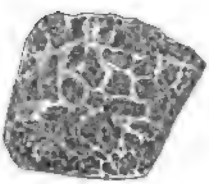


Fig. CVII.—PORTION OF MUCOUS MEMBRANE OF THE STOMACH, SLIGHTLY MAGNIFIED. The alveolar pits and small orifices of the tubular glands are seen (after Ecker).

Glands of mucous membranes.—Many, indeed most, of the glands of the body pour their secretions into the great passages lined by mucous membranes; but there are certain small glands which may be said to belong to the membrane itself, inasmuch as they are found in numbers over large tracts of that membrane, and yield mucus, or special secretions known to be derived from particular portions of the membrane. Omitting local peculiarities the glands referred to may be described as of three kinds, viz.:—

1. *Tubular glands.*—These are minute tubes formed by recesses or inversions of the basement membrane, and lined with epithelium. They are usually placed perpendicularly to the surface, and often very close together, and they constitute the chief substance of the mucous membrane in those parts where they abound, its apparent thickness depending on the length of the tubes, which differs considerably in different regions. The tubes open by one end on the surface; the other end is closed, and is either simple or loculated, or even cleft into two or more branches. The tubular glands are abundant in the stomach, and in the small and large intestines, where they are comparatively short and known as the crypts of Lieberkühn. They exist also in considerable numbers in the mucous membrane of the uterus.

2. *Small compound glands.*—Under this head are here comprehended minute but still true compound glands of the racemose kind, with single branched ducts of various lengths, which open on different parts of the membrane. Numbers of these, yielding a mucous secretion, open into the mouth and windpipe. They have the appearance of small solid bodies, often of a flattened lenticular form, but varying much both in shape and size, and placed at different depths below the mucous membrane on which their ducts open. The glands of Brunner, which form a dense layer in the commencing part of the duodenum, are of this kind.

3. *Solitary and agminated glands, conglobate glands* (Henle), *follicular glands* (Kölliker).—Found in various parts of the alimentary mucous membrane, also in the palpebral conjunctiva. They may be single (*solitary glands*), or in patches (*agminated glands*). Their structure is well known, but, although they are called glands, their function is still enigmatical. They are small sacs reaching down into the submucous tissue, closed and covered above by the mucous membrane. Within is fine retiform tissue, supporting radiating blood-capillaries, with bodies like lymph-corpuscles in the meshes, and communicating with a similar tissue (lymphoid tissue) diffused in the adjacent part of the membrane; for, although they do not open on the surface, their reticular capsule rarely forms a perfect inclosure. Several of these saccules are sometimes placed round a recess of

the mucous membrane which opens on the surface, and which may be simple, as in certain glands at the root of the tongue and in the pharynx, or complex and multilocular, as in the tonsils.

On the hypothesis that these bodies are really secreting glands, it has been presumed that they are occasionally opened by dehiscence for the discharge of their contents. According to another view they are dependencies of the lymphatic system, and there are various analogies and indications of relationship which might be adduced in favour of this opinion. On the other hand, it is not easy to see what special connection there can be between the lymphatic system and the collections of these bodies at the root of the tongue and in the tonsils, where, indeed, their presence is more reconcileable with the notion of their being secreting organs; in short, it must be confessed that the question as to their function has still to be answered.

Nerves.—The mucous membranes are supplied with nerves, and endowed with sensibility; but the proportion of nerves which they receive, as well as the degree of sensibility which they possess, differs very greatly in different parts. As to the mode of distribution and termination of their nerves, there is nothing to be said beyond what has been already stated in treating of the nerves in general.

Secretion.—Mucus is a more or less viscid, transparent, or slightly turbid fluid, of variable consistency. It is somewhat heavier than water, though expectorated mucus is generally prevented from sinking in that liquid by entangled air-bubbles. Examined with the microscope, it is found to consist of a fluid, containing solid particles of various kinds, viz., 1. Epithelium-particles detached by desquamation; 2. Mucus-corpuscles, which are bodies resembling much the pale corpuscles of the blood; 3. Granules and molecules occasionally. The viscidity of mucus depends on the liquid part, which contains a peculiar substance, named by the chemists *mucin.* This ingredient is precipitated and the mucus rendered turbid by the addition of water or a weak acid, but it may be partly redissolved in an excess of water, and completely so in a strong acid. This mucin is soluble in alkalies, and its acid solutions are not precipitated by ferrocyanide of potassium. Little can, of course, be expected from a chemical analysis of a heterogeneous and inseparable mixture of solid particles with a liquid solution, such as we find in mucus, which is, moreover, subject to differences of quality according to the part of the mucous membrane whence it is derived. Examined thus in the gross, however, the nasal mucus has been found to yield water, mucin, alcohol-extract with alkaline lactates, water-extract with traces of albumen and a phosphate, chlorides of sodium and potassium, and soda. Fat has been obtained by analysis of pulmonary mucus, reputed healthy.

Regeneration.—The reparatory process is active in the mucous membranes. Breaches of continuity occasioned by sloughing, ulceration, or other causes, readily heal. The steps of the process have been examined with most care in the healing of ulcers of the large intestine, and in such cases it has been found that the resulting cicatrix becomes covered with epithelium, but that the tubular follicles are not reproduced.

THE SKIN.

The skin consists of the cutis vera or corium, and the cuticle or epidermis.

The *epidermis*, *cuticle*, or *scarf-skin*, belongs to the class of epithelial structures, the general nature of which has been already considered. It forms a protective covering over every part of the true skin, and is itself quite insensible and non-vascular. The thickness of the cuticle varies in different parts of the surface, measuring in some not more than $\frac{1}{250}$th, and in others from $\frac{1}{24}$th to $\frac{1}{12}$th of an inch. It is thickest in the palms of the hands and soles of the feet, where the skin is much exposed to pressure, and it is not

improbable that this may serve to stimulate the subjacent true skin to a more active formation of epidermis; but the difference does not depend solely on external causes, for it is well marked, even in the fœtus.

Structure.—The cuticle is made up of flattened cells agglutinated together in many irregular layers. They at first contain nuclei with soft and moist contents, and, by successive formations beneath them, are gradually pushed to the free surface, become flattened in their progress into thin irregular scales, for the most part lose their nuclei, and are at last thrown off by desquamation. The deepest cells are elongated in figure, and placed perpendicularly on the surface of the corium (fig. CVIII. *b*), like the particles of columnar epithelium; they are denticulate at their lower ends, and fit into corresponding fine denticulations of the corium. These perpendicular cells generally form one, but in some places two or three strata; above them are cells of a more rounded shape, *c*. As the cells change their form, they undergo chemical and physical changes in the nature of their contents; for those in the deeper layers contain a soft, opaque, granular matter, soluble, as well as their envelope, in acetic acid, whilst the superficial ones are transparent, dry, and firm, and are not affected by that acid. It would seem as if their contents were converted into a horny matter, and that a portion of this substance is employed to cement them together. These dry, hard scales may be made to reassume their cellular form, by exposure for a few minutes to a solution of caustic potash or soda, and then to water. Under this treatment they are softened by the alkali and distended by imbibition of water.

Fig. CVIII.

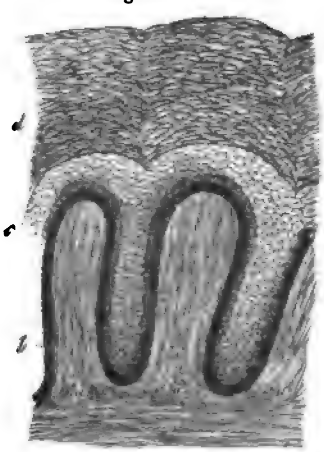


Fig. CVIII.—Skin of the Negro, in a vertical section, magnified 250 diameters.

a, *a*, cutaneous papillæ; *b*, undermost and dark-coloured layer of oblong vertical epidermis-cells; *c*, mucous or Malpighian layer; *d*, horny layer.

The more firm and transparent superficial part of the epidermis, *d*, may be separated from the deeper, softer, more opaque, and recently-formed part, which constitutes what is called the Malpighian layer, or *rete mucosum*, *c*.

Many of the cells of the cuticle contain pigment, and often give the membrane more or less of a tawny colour, even in the white races of mankind; the blackness of the skin in the negro depends entirely on the cuticle. The pigment is contained principally in the cells of the deep layer or rete mucosum, and appears to fade as they approach the surface, but even the superficial part possesses a certain degree of colour. More special details respecting the pigment have been already given (page lxiii).

The under or attached surface of the cuticle is moulded on the adjoining surface of the corium, and, when separated by maceration or putrefaction, presents impressions corresponding exactly with the papillary or other eminences, and the furrows or depressions of the true skin; the more prominent inequalities of the latter are marked also on the outer surface of the cuticle, but less accurately. Fine tubular prolongations of the cuticle sink down into the ducts of the sweat glands, and are often partially drawn out

from their recesses when the cuticle is detached, appearing then like threads proceeding from its under surface.

Chemical composition.—The cuticle consists principally of a substance peculiar to the epithelial and horny tissues, and named *keratin*. This horny matter is insoluble in water at ordinary temperatures, and insoluble in alcohol. It is soluble in the caustic alkalies. In composition, it is analogous to the albuminoid principles, but with a somewhat larger proportion of oxygen; like these, it contains sulphur. Besides keratin, the epidermis yields, on analysis, a small amount of fat, with salts, and traces of the oxides of iron and manganese. The tissue of the cuticle readily imbibes water, by which it is rendered soft, thick, and opaque, but it speedily dries again, and recovers its usual characters.

The *true skin*, *cutis vera*, *derma*, or *corium*, is a sentient and vascular texture. It is covered and defended, as already explained, by the insensible and non-vascular cuticle, and is attached to the parts beneath by a layer of areolar tissue, named "subcutaneous," which, excepting in a few parts, contains fat, and has therefore been called also the "panniculus adiposus" (fig. CXXIII. *d.*). The connection is in many parts loose and moveable, in others close and firm, as on the palmar surface of the hand and the sole of the foot, where the skin is fixed to the subjacent fascia by numerous stout fibrous bands, the space between being filled with a firm padding of fat. In some regions of the body the skin is moved by striated muscular fibres, which may be unconnected to fixed parts, as in the case of the orbicular muscle of the mouth, or may be attached beneath to bones or fasciæ, like the other cutaneous muscles of the face and neck, and the short palmar muscle of the hand.

Structure.—The corium consists of a *fibro-vascular layer*, which is supposed to be bounded at the surface next the cuticle, by a fine homogeneous *basement membrane* or *membrana propria*, like the corresponding part of the mucous membrane. No such superficial film can, it is true, be raised from the corium, but from its distinct presence in small gland ducts, which are continuous with the corium, and from the fact that a thin homogeneous membrane lies between the commencing cutis and cuticle in the embryo, it is presumed that a limitary membrane of this sort ought to be reckoned as an element of the corium, although, as in the analogous case of the mucous membrane, it cannot be shown to exist generally over the surface. The *fibro-vascular* part is made up of an exceedingly strong and tough framework of interlaced fibres, with blood-vessels and lymphatics. The fibres are chiefly of the white variety, such as constitute the chief part of the fibrous and areolar tissues, and are arranged in stout interlacing bundles, except at and near the surface, where the texture of the corium becomes very fine. With these are mixed yellow or elastic fibres, which vary in amount in different parts, but in all cases are present in smaller proportion than the former kind; also connective-tissue corpuscles, fusiform or ramified, and for the most part reticularly anastomosing. The interlacement becomes much closer and finer towards the free surface of the corium, and there the fibres can be discovered only by teasing out the tissue, which often acquires an almost homogeneous aspect. Towards the attached surface, on the other hand, the texture becomes much more open, with larger and larger meshes, in which lumps of fat and the small sudatory glands are lodged, and thus the fibrous part of the skin, becoming more and more lax and more mixed with fat, blends gradually with the subcutaneous areolar tissue to which it is allied in elementary constitution. Bundles of plain muscular tissue are distributed in the

substance of the corium wherever hairs occur; and their connection with the latter will be afterwards explained. Muscular bundles of the same kind are found in the subcutaneous tissue of the scrotum, penis, perineum, and areola of the nipple, as well as in the nipple itself. They join to form reticular superimposed layers, which are separated from the parts beneath by a stratum of simple lax areolar tissue, but towards the surface they are immediately applied to the corium. In the areola they are disposed circularly.

In consequence of this gradual transition of the corium into the subjacent tissue, its thickness cannot be assigned with perfect precision. It is generally said to measure from a quarter of a line or less to nearly a line and a half. As a general rule, it is thicker on the posterior aspect of the head, neck, and trunk, than in front; and thicker on the outer than on the inner side of the limbs. The corium, as well as the cuticle, is remarkably thick on the soles of the feet and palms of the hands. The skin of the female is thinner than that of the male.

For convenience of description it is not unusual to speak of the corium as consisting of two layers, the "reticular" and "papillary." The former, the more deeply-seated, takes no part in the construction of the papillæ, but contains in its meshes hair-follicles, cutaneous glands, and fat. The latter is divided into papillæ, and receives only the upper portion of the hair-follicles and glands, together with the termiual expansion of the vessels and nerves.

The free surface of the corium is marked in various places with larger or smaller furrows, which also affect the superjacent cuticle. The larger of them are seen opposite the flexures of the joints, as those so well known in the palm of the hand and at the joints of the fingers. The finer furrows intersect each other at various angles, and may be seen almost all over the surface; they are very conspicuous on the back of the hands. These furrows are not merely the consequence of the frequent folding of the skin by the action of muscles or the bending of joints, for they exist in the fœtus. The wrinkles of old persons are of a different nature, and are caused by the wasting of the soft parts which the skin covers. Fine curvilinear ridges, with intervening furrows, mark the skin of the palm and sole; these are caused by ranges of the papillæ, to be immediately described.

Papillæ.—The free surface of the corium is beset with small eminences

Fig. CIX.

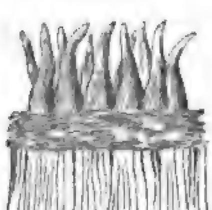


Fig. CX.

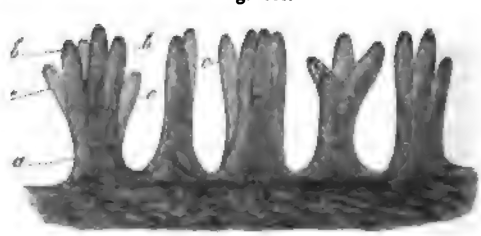


Fig. CIX.—Papillæ, as seen with a Microscope, on a portion of the True Skin, from which the Cuticle has been removed (after Breschet).

Fig. CX.—Compound Papillæ from the Palm of the Hand, magnified 60 diameters.

a, basis of a papilla; *b*, *b*, divisions or branches of the same; *c*, *c*, branches belonging to papillæ of which the bases are hidden from view (after Kölliker).

thus named, which seem chiefly intended to contribute to the perfection of the skin as an organ of touch, seeing that they are highly developed where the sense of touch is exquisite, and *vice versâ*. They serve also to extend the surface for the production of the cuticular tissue, and hence are large-sized and numerous under the nail. The papillæ are large, and in close array on the palm and palmar surface of the fingers, and on the corresponding parts of the foot (fig. CX.). There they are ranged in lines forming the curvilinear ridges seen when the skin is still covered with its thick epidermis. They are of a conical figure, rounded or blunt at the top, and sometimes cleft into two or more points, when they are named compound papillæ. They are received into corresponding pits on the under surface of the cuticle. In structure they resemble the superficial layer of the corium generally, and consist of a homogeneous tissue, presenting only faint traces of fibrillation, together with a few fine elastic fibres. On the palm, sole, and nipple, where they are mostly of the compound variety, they measure from $\frac{1}{200}$ to $\frac{1}{100}$ of an inch in height. In the ridges, the larger papillæ are placed sometimes in single but more commonly in double rows, with smaller ones between them (fig. CXXIII.), that is, also on the ridges, for there are none in the intervening grooves. These ridges are marked at short and tolerably regular intervals with notches, or short transverse furrows, in each of which, about its middle, is the minute funnel-shaped orifice of the duct of a sweat gland (fig. CXI). In other parts of the skin endowed with less sensibility, the papillæ are smaller, shorter, fewer in number, and irregularly scattered. On the face they are reduced to from $\frac{1}{800}$ to $\frac{1}{300}$ of an inch; and here they at parts disappear altogether, or are replaced by slightly elevated reticular ridges. In parts where they are naturally small, they often become enlarged by chronic inflammation round the margin of sores and ulcers of long standing, and are then much more conspicuous. Fine blood-vessels enter most of the papillæ, forming either simple capillary loops in each, or dividing into two or more capillary branches, according to the size of the papilla and its simple or composite form, which turn round in form of loops and return to the veins. Other papillæ receive nerves, to be presently noticed.

Fig. CXI.

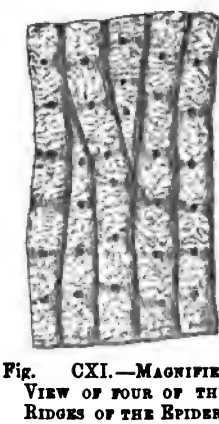


Fig. CXI.—Magnified View of four of the Ridges of the Epidermis, caused by rows of Papillæ beneath, with short Furrows or Notches across them; also the Openings of the Sudoriferous Ducts (after Breschet).

Blood-vessels and lymphatics.—The blood-vessels divide into branches in the subcutaneous tissue, and, as they enter the skin, supply capillary plexuses to the fat clusters, sweat glands, and hair follicles. They divide and anastomose still further as they approach the surface, and at length, on reaching it, form a dense network of capillaries, with rounded polygonal meshes. Fine branches are sent into the papillæ, as already mentioned. The lymphatics are abundant in some parts of the skin, as on the scrotum and round the nipple; whether they are equally so in all parts may be doubted. They form networks, which become finer as they approach the surface, and communicate underneath with straight vessels, and these, after a longer or a shorter course, join larger ones or enter lymphatic glands. The finest and most superficial network, although close to the surface of the corium, is

beneath the net of superficial blood-capillaries; in certain parts on the palm and sole, lymphatics pass into the papillæ, but do not reach their summits.

Nerves.—Nerves are supplied in very different proportions to different regions of the skin, and according to the degree of sensibility. They pass upwards towards the papillary surface, where they form plexuses, of which the meshes become closer as they approach the surface, and the constituent branches finer, so that the latter come at last to consist of only one or two primitive fibres. The fibres also become more attenuated the further they proceed towards their final destination. In the finest and most superficial part of the plexus, the ultimate fibres, or at least some of them, undergo actual division. Little more can be said of the termination of nerves on the general cutaneous surface. A large share of the cutaneous nerves is distributed to the hair-follicles, whilst some end in special terminal organs, namely, *end-bulbs*, *tactile corpuscles*, and *Pacinian bodies*. The last-named bodies are seated in the subcutaneous tissue. End-bulbs are found on the glans penis and glans clitoridis, and in some of the papillæ on the red border of the lips. The tactile corpuscles of the skin are more numerous; they are found in certain papillæ of the palm and sole, more sparingly in those of the back of the hand and foot, the palmar surface of the fore-arm and the nipple. Such papillæ commonly contain no blood-vessels, and are named "tactile," as distinguished from the "vascular" papillæ which receive no nerves. Sometimes, however, a tactile and a vascular papilla may spring from the same stem. The structure of these different terminal corpuscles has been already described (pages cl to clv).

Chemical composition.—The corium being composed chiefly of white fibrous tissue, has a corresponding chemical composition. It is, accordingly, in a great measure, resolved into gelatin by boiling, and hence, also, its conversion into leather by the tanning process.

Development of the cutis.—The cutis consists at first of cells which may in animals be traced back to the first formative cells of the embryo. Many of them give rise to connective tissue; others to vessels and nerves; and a third portion is converted into fat-cells. No doubt the muscular tissue also originates from cells. The mode of formation of these several elementary tissues has been already described. Progressive development takes place from within outwards, so that the papillæ are formed latest.

The *cuticle* at first differs in no point from the cutis, but consists of the earliest formative cells. Their subsequent metamorphoses and the mode of production of new cells have not been accurately determined; the question has been already considered at page lv.

Nails and *hairs.*—The nails and hairs are growths of the epidermis, agreeing essentially in nature with that membrane; their epidermic tissue is destitute of vessels and nerves, and separable from the cutis.

Nails.—The posterior part of the nail which is concealed in a groove of the skin is named its "root," the uncovered part is the "body," which terminates in front by the "free edge." A small portion of the nail near the root, named from its shape the *lunula*, is whiter than the rest. This appearance is due partly to some degree of opacity of the substance of the nail at this point, and partly to the skin beneath being less vascular than in front.

The part of the corium to which the nail is attached, and by which in fact it is secreted or generated, is named the *matrix*. This portion of the skin is highly vascular and thickly covered with large vascular papillæ.

Posteriorly the matrix forms a crescentic groove or fold, deep in the middle but getting shallower at the sides, which lodges the root of the nail; the rest of the matrix, before the groove, is usually named the *bed* of the nail. The small lighter-coloured part of the matrix next the groove and corresponding with the lunula of the nail, is covered with papillæ having no regular arrangement, but the whole remaining surface of the matrix situated in front of this, and supporting the body of the nail, is marked with longitudinal and very slightly diverging ridges cleft at their summits into rows of papillæ. These ridges, or *laminæ*, as they are sometimes, and perhaps more suitably, named, fit into corresponding furrows on the under surface of the nail. The cuticle, advancing from the back of the finger, becomes attached to the upper surface of the nail near its posterior edge, that is, all round the margin of the groove in which the nail is lodged; in front the cuticle of the point of the finger becomes continuous with the under surface of the nail a little way behind its free edge.

The nail, like the cuticle, is made up of scales derived from flattened cells. The oldest and most superficial of these are the broadest and hardest, but at the same time very thin and irregular, and so intimately and confusedly connected together that their respective limits are scarcely discernible. They form the exterior, horny part of the nail, and cohere together in irregular layers, so as to give this part a lamellar structure. On the other hand, the youngest cells, which are those situated at the root and under surface, are softer and of a rounded or polygonal shape. The deepest layer differs somewhat from the others, in having its cells elongated, and arranged perpendicularly, as in the case of the epidermis. Thus the under part of the nail (fig. CXII. B) corresponds in nature with the Malpighian or mucous layer of the epidermis, and the upper part (C) with the horny layer. As in the case of the epidermis, the hardened scales may be made to reassume their cellular character by treatment with caustic alkali, and afterwards with water; and then it is seen that they still retain their nuclei. In chemical composition the nails resemble epidermis; but, according to Mulder, they contain a somewhat larger proportion of carbon and sulphur.

Fig. CXII.

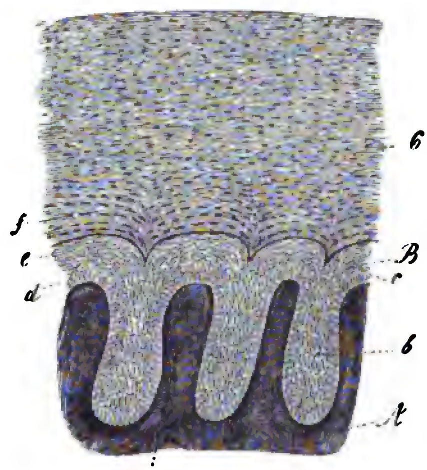


Fig. CXII.—VERTICAL TRANSVERSE SECTION THROUGH A SMALL PORTION OF THE NAIL AND MATRIX, LARGELY MAGNIFIED (after Kölliker).

A, corium of the nail-bed, raised into ridges or laminæ, *a*, fitting in between corresponding laminæ, *b*, of the nail; B, Malpighian, and C, horny layer; *d*, deepest and vertical cells; *e*, upper flattened cells of Malpighian layer.

The growth of the nail is effected by a constant generation of cells at the

root and under surface. Each successive series of these cells being followed and pushed from their original place by others, become flattened into dry, hard, and inseparably coherent scales. By the addition of new cells at the posterior edge the nail is made to advance, and by the apposition of similar particles to its under surface it grows in thickness; so that it is thicker at the free border than at the root. The nail being thus merely an exuberant part of the epidermis, the question at one time raised, whether that membrane is continued underneath it, loses its significance. When a nail is thrown off by suppuration, or pulled away by violence, a new one is produced in its place, provided the matrix remains.

Development in the fœtus.—In the third month of intra-uterine life the part of the embryonic corium which becomes the matrix of the nail is marked off by the commencing curvilinear groove, which limits it posteriorly and laterally. The epidermis on the matrix then begins to assume, in its under part, the characters of a nail, which might, therefore, be said to be at first covered over by the embryonic cuticle. After the end of the fifth month it becomes free at the anterior border, and in the seventh month decidedly begins and thenceforth continues to grow in length. At birth the free end is long and thin, being manifestly the earlier-formed part which has been pushed forward. This breaks or is pared off after birth, and, as the infantile nail continues to grow, its flattened cells, at first easily separable, become harder and more coherent, as in after life.

Hairs.—A hair consists of the root, which is fixed in the skin, the shaft or stem, and the point. The *stem* is generally cylindrical, but often more or less flattened; sometimes it is grooved along one side, and therefore reniform in a cross section: when the hair is entire it becomes gradually smaller towards the point. The length and thickness vary greatly in different individuals and races of mankind as well as in different regions of the body. Light-coloured hair is usually finer than black.

Fig. CXIII.

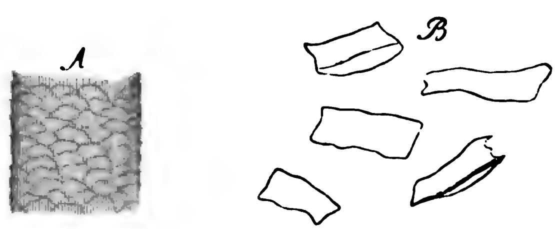


Fig. CXIII.—A, Surface of a White Hair, magnified 160 diameters. The Waved Lines mark the upper or free Edges of the Cortical Scales. B, Separated Scales, magnified 350 diameters (after Kölliker).

The stem is covered with a coating of finely-imbricated scales, the upwardly projecting serrated edges of which give rise to a series of fine waved transverse lines, which may be seen with the microscope on the surface of the hair (fig. cxiii. a). Within this scaly covering, by some called the *hair-cuticle*, is a *fibrous substance* which in all cases constitutes the chief part and often the whole of the stem; but in many hairs the axis is occupied by a substance of a different nature, called the *medulla* or *pith*, for which reason the surrounding fibrous part is often named "cortical,"

although this term is more properly applied to the superficial coating of scales above mentioned. The *fibrous substance* is translucent, with short longitudinal opaque streaks of darker colour intermixed. It may be broken up into straight, rigid, longitudinal fibres, which, when separated, are found to be flattened, broad in the middle, where they measure $\frac{1}{4450}$ of an inch in breadth, and pointed at each end, with dark and rough edges. The fibres may be resolved into flattened cells of a fusiform outline; these are mostly transparent, or marked with only a few dark specks. The colour of the fibrous substance is caused by oblong patches of pigment-granules, and generally diffused colouring matter of less intensity. Very slender elongated nuclei are also discovered by means of reagents, whilst specks or marks of another description in the fibrous substance are occasioned by minute irregularly-shaped cavities containing air. These air-lacunules are abundant in white hairs, and in very dark hairs may be altogether wanting; they are best seen too in the former, in which there is no risk of deception from pigment-specks. Viewed by transmitted light they are dark, but brilliantly white by reflected light. When a white hair has been boiled in water, ether, or oil of turpentine, these cavities become filled with fluid, and are then quite pellucid; but when a hair which has been thus treated is dried, the air quickly finds its way again into the lacunæ, and they resume their original aspect.

The medulla or pith, as already remarked, does not exist in all hairs. It is wanting in the fine hairs over the general surface of the body, and is not commonly met with in those of the head; nor in the hairs of children under five years. When present it occupies the centre of the shaft and ceases towards the point. It is more opaque and deep-coloured than the fibrous part; in the white hairs of quadrupeds it is white, but opaque and dark when seen by transmitted light. It seems to be composed of little clusters of cells, differing in shape, but generally angular, and containing minute particles, some resembling pigment-granules, and others like very fine fat granules, but really for the most part air-particles, apparently included in some solidified tenaceous substance. The whole forms a continuous dark mass along the middle of the stem, interrupted at parts for a greater or less extent. In the latter case, the axis of the stem at the interruptions may be fibrous like the surrounding parts, or these intervals may be occupied by a clear, colourless matter; and, according to Henle, some hairs present the appearance of a sort of canal running along the axis and filled in certain parts with opaque granular matter, and in others with a homogeneous transparent substance.

The *root* of the hair is lighter in colour and softer than the stem; it swells out at its lower end into a bulbous enlargement or knob (fig. CXIV. *c*), and is received into a recess of the skin named the *hair-follicle*, which, when the hair is of considerable size, reaches down into the subcutaneous fat. The follicle, which receives near its mouth the opening ducts of one or more sebaceous glands (*k*, *k*), is somewhat dilated at the bottom, to correspond with the bulging of the root; it consists of an outer coat continuous with the corium (fig. CXIV. *g*, *h*; CXV. *d*, *d*), and an epidermic lining (fig. CXIV. *e*, *f*; CXV. *b*, *c*), continuous with the cuticle. The outer or *dermic* coat is thin but firm, and consists of three layers. The most external is formed of connective tissue in longitudinal bundles, without any elastic fibres, but with numerous long fusiform corpuscles. It is highly vascular, and possesses nervous fibrils. It is intimately connected above with the corium, and determines the form of the follicle. The most

internal layer (*hyaline coat*, Kölliker) is a transparent homogeneous membrane, marked transversely on its inner surface with some raised lines, and not reaching so high as the mouth of the follicle ; it corresponds with the

Fig. CXIV.

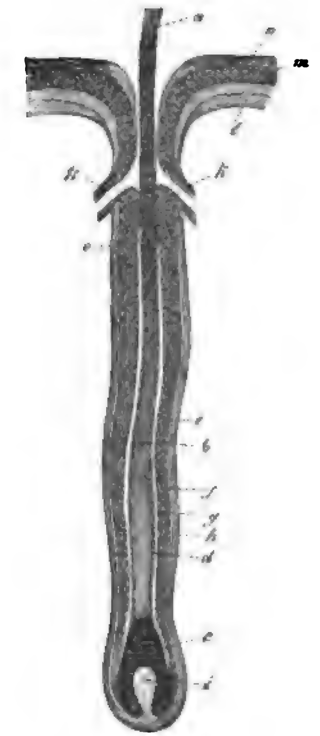


Fig. CXIV.—Medium-sized Hair in its Follicle, magnified 50 diameters (from Kölliker).

a, stem cut short ; *b*, root ; *c*, knob ; *d*, hair cuticle ; *e*, internal, and *f*, external root-sheath ; *g*, *h*, dermic coat of follicle ; *i*, papilla ; *k k*, ducts of sebaceous glands ; *l*, corium ; *m*, mucous layer, and *n*, horny layer of epidermis ; *o*, upper limit of internal root-sheath (from Kölliker).

Fig. CXV.

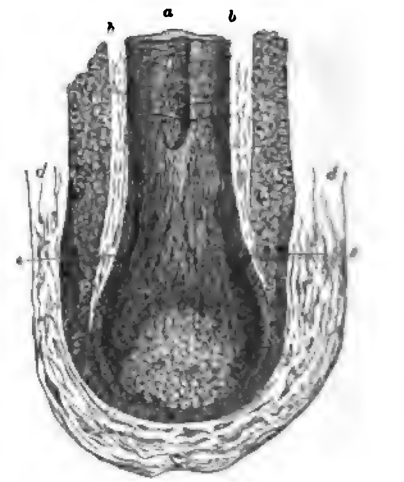


Fig. CXV.—Magnified View of the Root of a Hair (after Kohlräusch).

a, stem or shaft of hair cut across ; *b*, inner, and *c*, outer layer of the epidermic lining of the hair-follicle, called also the inner and outer root-sheath ; *d*, dermic or external coat of the hair-follicle, shown in part ; *e*, imbricated scales about to form a cortical layer on the surface of the hair. The adjacent cuticle of the root-sheath is not represented, and the papilla is hidden in the lower part of the knob where that is represented lighter.

membrana propria or basement membrane of analogous structures. Between the two is a layer extending from the bottom of the follicle as high as the entrance of the sebaceous glands, composed of an indistinctly fibrous matrix, tearing transversely, and of transversely disposed fusiform connective tissue corpuscles, with oblong nuclei. This layer, which seems to be a form of connective tissue, receives capillary blood-vessels, but without as yet recognised nerves. The *epidermic lining* adheres closely to the root of the hair, and commonly separates, in great part, from the follicle and abides by the hair when the latter is pulled out ; hence it is sometimes named the "root-sheath." It consists of an outer, softer, and more opaque stratum (fig. cxv., *c*, *c*) next the dermic coat of the follicle, and an internal more transparent layer (*b*, *b*) next the hair. The former, named also the *outer root-sheath*, and by much the thicker of the two, corresponds with the

mucous or Malpighian layer of the epidermis in general, and contains soft growing cells, including pigment in the coloured races, which at the lower part form a much thinner stratum and pass continuously into those of the hair-knob; the internal layer or *inner root-sheath* represents the superficial or horny layer of the epidermis according to some authorities; but others maintain that it is not continuous with that part of the skin, but ceases abruptly a little below the orifices of the sebaceous ducts. When detached from the hair it is found to be covered internally with imbricated downwardly-projecting scales, forming the *cuticle of the root-sheath*, which is applied to the cortical scaly cuticle of the hair proper, to whose upwardly-directed scales it fits like a mould. Its scales, as well as those of the hair-cuticle, pass, at the bottom of the follicle, into the round cells of the hair-knob. Now, after reckoning off this cuticular lining, the inner root-sheath still consists of two layers, which towards the bottom of the follicle become blended into one. The innermost (that next the cuticula) is known as *Huxley's layer*; it consists of flattened polygonal nucleated cells, two or even three deep. The outer layer is composed of oblong, somewhat flattened cells without nuclei, in which fissures and holes are liable to occur from accidental laceration, so as to give it the aspect of a perforated or fenestrated membrane. At the lower part both layers pass into a single layer of large polygonal nucleated cells without openings between them.

The soft bulbous enlargement of the root of the hair is attached by its base to the bottom of the follicle, and at the circumference of this attached part it is continuous with the epidermic lining. At the bottom of the follicle it, in fact, takes the place of the epidermis, of which it is a growth or extension, and this part of the follicle is the true matrix of the hair, being, in reality, a part of the corium (though sunk below the general surface), which supplies material for the production of the hair. This productive part of the follicle is, accordingly, remarkably vascular; in the large tactile hairs on the snout of the seal and some other animals it is raised in form of a conical vascular papilla or pulp, which fits into a corresponding excavation of the hair root, and Kölliker states that a vascular eminence of similar structure exists in the hairs generally, both small and large, of man as well as quadrupeds. As the follicle, in short, is a recess of the corium, so the hair-papilla is a cutaneous papilla sunk in the bottom of it. The papilla is described as being commonly of an ovoid shape and attached to the bottom of the follicle by a narrow base, or a sort of pedicle (fig. CXIV., *i*). Nervous branches of considerable size enter the follicles of the large tactile hairs referred to, but their final distribution has not been traced; the pain occasioned by pulling the hair seems to indicate that the human hair-follicles are not unprovided with nerves.

Fine muscles, each formed of a slender bundle of plain muscular tissue, are connected with the hair-follicles (fig. CXVI.). Their mode of attachment is described by Kölliker and Lister to be the following: they arise from the most superficial part of the corium, and pass down obliquely to be inserted into the outside of the follicle below the sebaceous glands. They are placed on the side to which the hair slopes, so that their action in elevating the hair is evident. Some anatomists have also recently described a layer of circularly-disposed muscular cells as applied immediately to the outside of the follicle.

Growth of hair.—On the surface of the papilla or vascular matrix, at the bottom of the follicle, there is a growth of nucleated cells. The cells for the most part lengthen out and unite into the flattened fibres which compose

the fibrous part of the hair, and certain of them, previously getting filled with pigment, give rise to the coloured streaks and patches in that tissue; their nuclei, at first, also lengthen in the same manner, but, at last, partly become indistinct. The cells next the circumference expand into the scales which form the imbricated cuticular layer (fig. cxv., *e*, *e*). The medulla, where it exists, is formed by the cells nearest the centre; these retain their primitive figure longer than the rest; they become coherent, and their cavities may coalesce together by destruction of their mutually adherent parietes, whilst collections of pigment granules make their appearance in them and around their nuclei, forming an opaque mass, which occupies the axis of the hair.

Fig. CXVI.

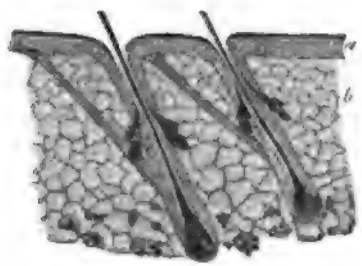


Fig. CXVII.

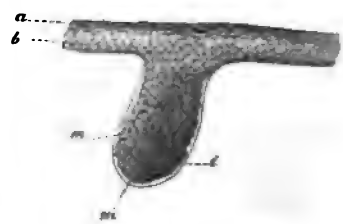


Fig. CXVI.—Section of the Skin of the Head, with two Hair Follicles, slightly magnified (from Kölliker).

a, epidermis; *b*, corium; *c*, muscles of the hair-follicles.

Fig. CXVII.—Hair Rudiment from an Embryo of Six Weeks, magnified 350 diameters (after Kölliker).

a, horny, and *b*, mucous or Malpighian layer of cuticle; *i*, limitary membrane; *m*, cells, some of which are assuming an oblong figure, which chiefly form the future hair.

The substance of the hair, of epidermic nature, is, like the epidermis itself, quite extravascular, but, like that structure also, it is organised and subject to internal organic changes. Thus, in the progress of its growth, the cells change their figure, and acquire greater consistency. In consequence of their elongation, the hair, bulbous at the commencement, becomes reduced in diameter and cylindrical above. But it cannot be said to what precise distance from the root organic changes may extend. Some have imagined that the hairs are slowly permeated by a fluid, from the root to the point, but this has not been proved. The sudden change of the colour of the hair from dark to grey, which sometimes happens, has never been satisfactorily explained.

Development of the hair in the fœtus.—The rudiments of the hairs may be discerned at the end of the third or beginning of the fourth month of intra-uterine life, as little black specks beneath the cuticle. They at first appear as little pits in the corium (fig. cxvii.), filled with cells of precisely the same nature as those of the Malpighian or mucous layer of the cuticle, with which they are continuous; so it might correctly be said that the hair rudiments are formed of down growths of the mucous layer, which sink into the corium. A homogeneous limiting membrane next appears (*i*), inclosing the collection of cells, and continuous above with a similar simple film which at this time lies between the cuticle and the corium; it becomes the innermost or hyaline layer of the dermic coat of the follicle. The hair rudiments next lengthen and swell out at the bottom, so as to assume a flask-shape (fig. cxviii).

Cells are deposited outside the limitary membrane, which eventually give rise to fibres, corpuscles, and other constituents of the dermic coat. While this is going on outside, the cells within the follicle undergo changes. Those in the middle lengthen out conformably with the axis of the follicle, and give rise to the appearance of a short conical miniature hair, faintly distinguishable by difference of shade from the surrounding mass of cells, which are also slightly elongated, but across the direction of the follicle. The papilla (figs. CXVIII., &c., *h*) makes its appearance at the swollen root of the little hair; and the residuary cells contained within the rudimentary follicle form the root sheath, the inner layer of which, or inner root-sheath, lying next to the hair (fig. CXIX., *d*), is soon distinguished by its translucency from the more opaque outer part that fills up the rest of the cavity. The young hair continuing to grow, at last perforates the cuticle (fig. CXX., *g*), either directly, or after first slanting up for some way between the mucous and horny strata. The young hair is often bent like a whip, and then the double part protrudes.

Fig. CXVIII.

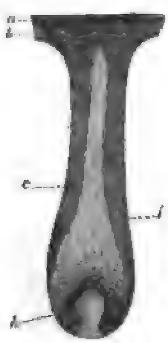


Fig. CXIX.

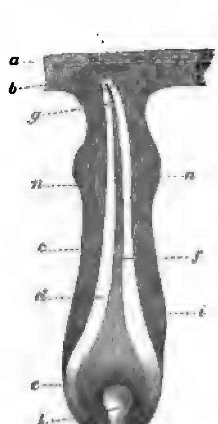


Fig. CXX.

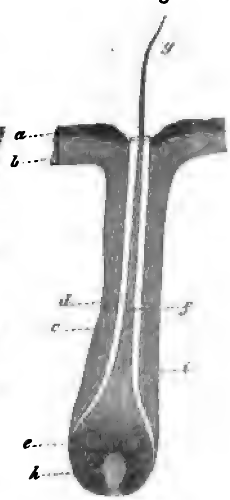


Fig. CXVIII.—RUDIMENT OF A HAIR OF THE EYEBROW, MAGNIFIED 50 DIAMETERS (after Kölliker).

The cells form an internal cone indicating the position of the future hair. *a*, horny layer of cuticle; *b*, mucous layer; *c*, external layer of root sheath; *i*, limitary membrane; *h*, papilla.

Fig. CXIX.—HAIR RUDIMENT MEASURING 0·22 OF A LINE, FROM THE EYEBROW, WITH THE YOUNG HAIR NOT YET RISEN THROUGH THE CUTICLE (after Kölliker).

a, *b*, *c*, *h*, *i*, as in fig. CXVIII; *e*, hair knob; *f*, stem, and *g*, point of the hair; *d*, internal layer of the root sheath, still inclosing the hair; *n*, *n*, commencing sebaceous follicles.

Fig. CXX.—HAIR FOLLICLE FROM THE EYEBROW WITH THE HAIR JUST ERUPTED; THE INNER LAYER OF THE ROOT-SHEATH RISES TO THE MOUTH OF THE HAIR FOLLICLE (after Kölliker.)

The letters denote the same parts as in Fig. CXIX.

The first hairs produced constitute the *lanugo*; their eruption takes place about the fifth month of intra-uterine life, but part of them are shed before birth, and are found floating in the liquor amnii. Kölliker affirms that the infantile hairs are entirely shed and renewed within a few months after birth; those of the general sur-

face first, and afterwards the hairs of the eyelashes and head, which he finds in process of change in infants about a year old.

The new hairs are generated in the follicles of the old (figs. cxxi. and cxxii.). An increased growth of cells takes place in the soft hair-knob, and in the adjoining part of the root-sheath (the outer layer); the growing mass pushes up the hair-knob, and detaches it from its generative papilla. The newly-formed mass of cells, occupying the lower part of the follicle, and resting on the papilla, is gradually converted into a new hair with its root-sheath, just as in the primitive process of formation in the embryo; and as the new hair lengthens and emerges from the follicle, the old one, separated from its matrix by the interposition of the new growth, is gradually pushed towards the opening, and at last falls out, its root-sheath having previously undergone partial absorption. When a hair is pulled out, a new one grows in its place, provided the follicle (from which the growth proceeds) remains entire. Heusinger, who experimentally studied the process in the large hairs situated on the lips of the dog, found that a new hair appeared above the surface in a few days after the evulsion of the old one, and attained its full size in about three weeks.

Fig. CXXI.

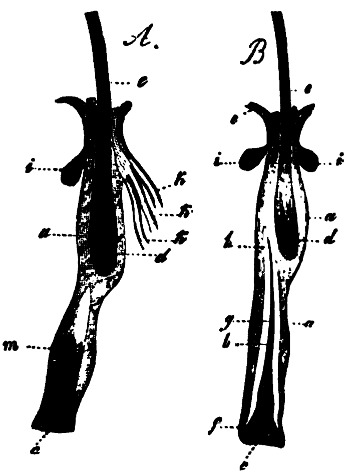


Fig. CXXII.

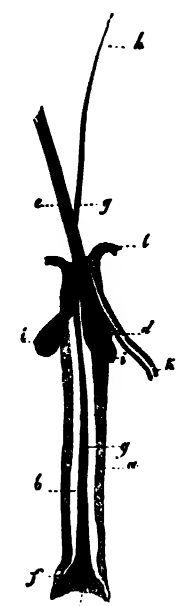


Fig. CXXI.—Two Eyelashes of an Infant, pulled out from their Follicles, magnified 20 diameters (from Kölliker).

A, the new cell-growth forming a cone, *m*, in the interior (as in fig. cxviii.). In B, the cone has separated into the new hair, *f*, *g*, and its inner root-sheath, *b*; *a*, outer, and *b*, inner root-sheath of new hair; *c*, pit for papilla; *d* and *e*, the knob and stem of old hair; *f*, knob; *g*, stem; and *h*, the point of new hair; *i*, sebaceous glands; *k*, *k*, sweat-glands here opening into mouth of hair-follicle.

Fig. CXXII.—Eyelash of an Infant, with Young Hair come forth, magnified 20 diameters (from Kölliker).

l, epidermis continuous with outer root-sheath; other letters as in preceding figures.

Distribution and arrangement.—Hairs are found on all parts of the skin except the palms of the hands and soles of the feet, the dorsal surface of the third phalanges of the fingers and toes, the upper eyelids, the glans, and the inner surface of the prepuce.

On the head they are set in groups, on the rest of the skin for the most part singly. Except those of the eyelashes, which are implanted perpendicularly to the surface, they have usually a slanting direction, which is wonderfully constant in the same parts.

Chemical nature.—The chemical composition of hair has been investigated principally by Vauquelin, Scherer, and Van Laer. When treated with boiling alcohol, and with ether, it yields a certain amount of oily fat, consisting of margarin, margaric acid, and olein, which is red or dark coloured, according to the tint of the hair. The animal matter of the hair thus freed from fat, is supposed to consist of a substance yielding gelatin, and a protein compound containing a large proportion of sulphur. It is insoluble in water, unless by long boiling under pressure, by which it is reduced into a viscid mass. It readily and completely dissolves in caustic alkalies. By calcination, hair yields from 1 to 1½ per cent. of ashes, which consist of the following ingredients—viz., peroxide of iron, and according to Vauquelin, traces of manganese, silica, chlorides of sodium and potassium, sulphates of lime and magnesia, and phosphate of lime. With the exception of the bones and teeth, no tissue of the body withstands decay after death so long as the hair, and hence it is often found preserved in sepulchres, when nothing else remains but the skeleton.

Glands of the skin.—These are of two kinds, the sweat glands, and the sebaceous, which yield a fatty secretion.

Fig. CXXIII.

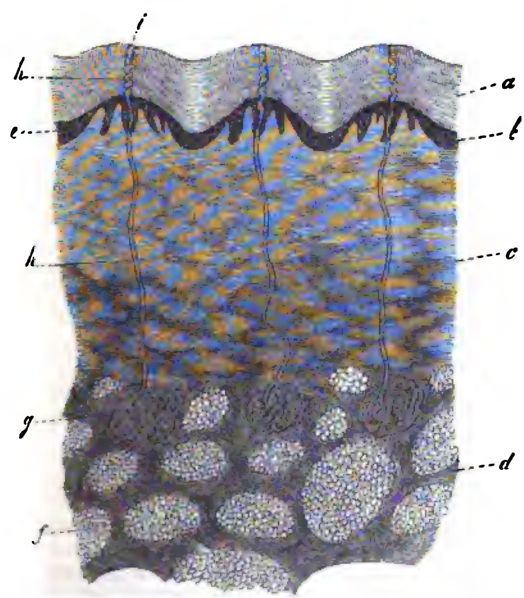


Fig. CXXIV.

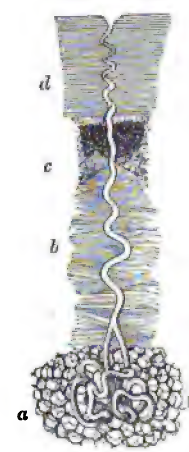


Fig. CXXIII.—Vertical Section of the Skin and Subcutaneous Tissue, from end of the Thumb, across the Ridges and Furrows, magnified 20 diameters (from Kölliker).

a, horny, and *b*, mucous layer of the epidermis ; *c*, corium ; *d*, *panniculus adiposus* ; *e*, papillæ on the ridges ; *f*, fat clusters ; *g*, sweat-glands ; *h*, sweat-ducts ; *i*, their openings on the surface.

Fig. CXXIV.—Magnified View of a Sweat-Gland with its Duct (after Wagner).

a, the gland surrounded by vesicles of adipose tissue ; *b*, the duct passing through the corium ; *c*, its continuation through the lower, and *d*, through the upper part of the epidermis.

The sudoriferous glands or *sweat-glands* (figs. CXXIII. and CXXIV.).—These are seated on the under surface of the corium, and at variable depths in the subcutaneous adipose tissue. They have the appearance of small round reddish bodies, each of which, when examined with the microscope, is found to consist of a fine tube, coiled up into a ball (though sometimes forming an irregular or flattened figure), from which the tube is continued, as the duct of the gland, upwards through the true skin and cuticle, and opens on the surface by a slightly widened orifice. The duct, as it passes through the epidermis, is twisted like a corkscrew, that is, in parts where the epidermis is sufficiently thick to give room for this; lower down it is but slightly curved. Sometimes the duct is formed of two coiled-up branches, which join at a short distance from the gland, as happens to be the case in the specimen represented in figure CXXIV. The tube, both in the gland and where it forms the excretory duct, consists of an outer coat, continuous with the corium, and reaching no higher than the surface of the true skin, a thin homogeneous membrana propria, and an epithelial lining, consisting of one or more strata of cells (often containing brownish pigment), and continuous with the epidermis, which alone forms the twisted part of the duct. The outer, dermic or fibrous, coat is formed of homogeneous or finely fibrous connective tissue with corpuscles. The larger gland-ducts in the axilla, at the root of the penis, on the labia majora, and in the neighbourhood of the anus, contain between their coats a layer of non-striated muscular fibres, arranged longitudinally. In the larger glands, moreover, the duct is rarely simple, being more usually parted by repeated dichotomous division into several branches, which before ending give off short cæcal processes; in rare cases the branches anastomose. On carefully detaching the cuticle from the true skin, after its connection has been loosened by putrefaction, it usually happens that the cuticular linings of the sweat-ducts get separated from their interior to a certain depth, and are drawn out in form of short threads attached to the under surface of the epidermis. The coils of the duct are loosely held together by connective tissue, which may form a sort of capsule round the body of the gland. Each little sweat-gland is supplied with a dense cluster of capillary blood-vessels.

The *contents* of the smaller sweat-glands are fluid, without any formed elements; but in the larger sweat-glands of the axilla the contents are semi-fluid, and abound in fine pale granules and nuclei; or their secretion is extremely viscid, with a varying quantity of large, opaque, colourless, or yellow granules, with nuclei and cells, similar to epithelium cells; and in both cases it may also contain fat. Kölliker states that from the nature of their contents these larger glands might be separated into a distinct group from the ordinary sweat-glands, were it not for the presence of transitional forms.

Distribution.—Sweat-glands exist in all regions of the skin, and attempts have been made to determine their relative amount in different parts, for they are not equally abundant everywhere; but while it is easy to count their numbers in a given space on the palm and sole, the numerical proportion assigned to them in most other regions must be taken with considerable allowance. According to Krause, nearly 2,800 open on a square inch of the palm of the hand, and somewhat fewer on an equal extent of the sole of the foot. He assigns rather more than half this number to a square inch on the back of the hand, and not quite so many to an equal portion of surface on the forehead, and the front and sides of the neck; then come the breast, abdomen, and fore arm, where he reckons about 1100 to the inch, and lastly, the lower limbs and the back part of the neck and trunk, on which the number in the same space is not more than from 400 to 600.

The *size* of the sweat-glands also varies. According to the observer last named, the average diameter of the round-shaped ones is about one-sixth of a line; but in some parts they are larger than this—as, for example, in the groin, but especially in

the axilla. In this last situation, Krause found the greater number to measure from one-third of a line to a line, and some nearly two lines in diameter.

The *development* of the sweat-glands has been carefully studied by Kölliker. He states that their rudiments, when first discoverable in the embryo, have much the same appearance as those of the hairs, and, in like manner, consist of processes of the mucous layer of the epidermis, which pass down and are received into corresponding recesses of the corium. They are formed throughout of cells collected into a solid mass of an elongated-pyriform, or rather club shape, continuous by its small end with the soft layer of the cuticle, and elsewhere surrounded by a homogeneous limiting membrane, which is prolonged above between the corium and cuticle. The subsequent changes consist in the elongation of the rudimentary gland, the formation of a cavity along its axis—at first without an outlet—the prolongation of its canal through the epidermis to open on the surface, and, in the mean time, the coiling up of the gradually lengthening gland-tube into a compact ball, and the twisting of the excretory duct as it proceeds to the orifice. The original homogeneous membrane of the duct becomes thickened and is continuous with the surface of the corium, whilst an epithelium appears within, consisting of several layers of polygonal or rounded cells. The ceruminous glands in the auditory passage are known to consist of a tube coiled into a rounded or oval ball, like the sweat-glands; and the investigations of Professor Kölliker show such a further correspondence between the two, in structure and mode of development, as to lead him to regard the ceruminous glands as a mere local variety of the sudoriferous, which, as above noticed, present specialities both of structure and secretion in particular regions of the body.

Fig. CXXV.

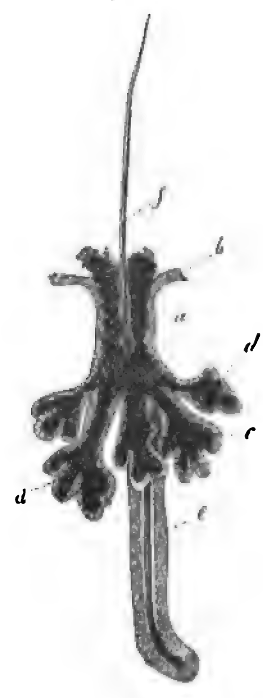


Fig. CXXV.—Sebaceous Gland from the Face with branched duct, opening into a Hair-Follicle, magnified 50 diameters (from Kölliker).

a, epithelium continuous with *b*, the mucous layer of epidermis; *c*, contents of gland; *d*, *d*, the groups of saccules on the branches of the duct; *e*, hair-follicle; *f*, hair.

The *sebaceous glands* (fig. cxxv.), pour out their secretion at the roots of the hairs, for, with very few exceptions, they open into the hair follicles, and are found wherever there are hairs. Each has a small duct, which opens at a short distance within the mouth of the hair follicle, and, by its other end, leads to a cluster of small rounded secreting saccules, which, as well as the duct, are lined by epithelium, and usually charged with the fatty secretion, mixed with detached epithelium particles. The number of saccular recesses connected with the duct usually varies from four or five to twenty; it may be reduced to two or three, in very small glands, or even to one, but this is rare. These glands are lodged in the substance of the corium. Several may open into the same hair follicle, surrounding it on all sides, and their size is not regulated by the magnitude of the hair. Thus, some of the largest are connected with the fine downy hairs on the alæ of the nose and other parts of the face, and there they often become unduly charged with pent-up secretion.*

* A few years ago it was discovered by Dr. Gustavus Simon, that the sebaceous and

Development of the sebaceous glands.—The rudiments of the sebaceous glands sprout like little buds from the sides of the hair follicles; they are at first, in fact, excrescences of the external or mucous layer of the root-sheath (fig. cxix., *n*, *n*), and are composed entirely of nucleated cells. Each little process soon assumes a flask shape and is at first solid; but in due time a group of cells containing fat particles appears in its centre, and gradually extends itself along the axis of the pedicle until it penetrates through the root-sheath, and the fat cells thus escape into the cavity of the hair follicle, and constitute the first secretion of the sebaceous gland. They are soon succeeded by others of the same kind, and the little gland is established in its office. Additional saccules and recesses, by which the originally simple cavity of the gland is complicated, are formed by budding-out of its epithelium, as the first was produced from the epithelial root-sheath, and are excavated in a similar manner.

It would thus appear that the rudiments of the hair follicles, sweat-glands and sebaceous glands, are all derived from the same source. They all originally appear as solid bud-like excrescences of the soft Malpighian or mucous layer of the epidermis, for the outer stratum of the root-sheath must be regarded as such; these grow down into the corium, in which recesses are formed to receive them, and which, of course, yields the material required both for the production of new cells for their further growth and for the maintenance of their secreting function.

Functions and vital properties of the skin.—The skin forms a general external tegument to the body, defining the surface, and coming into relation with foreign matters externally, as the mucous membrane, with which it is continuous and in many respects analogous, does internally. It is also a vast emunctory, by which a large amount of fluid is eliminated from the system, in this also resembling certain parts of the mucous membrane. Under certain conditions, moreover, it performs the office of an absorbing surface, but this function is greatly restricted by the epidermis. Throughout its whole extent the skin is endowed with *tactile sensibility*, but in very different degrees in different parts. On the skin of the palm and fingers, which is largely supplied with nerves and furnished with numerous prominent papillæ, the sense attains a high degree of acuteness; and this endowment, together with other conformable arrangements and adaptations, invests the human hand with the character of a special organ of touch. A certain though low degree of vital contractility, depending doubtless on the muscular fibres in its tissue, also belongs to the skin. This shows itself in the general shrinking of the skin caused by naked exposure to cold and by certain mental emotions, and producing the state of the surface named "cutis anserina," in which the muscular bundles protrude the hair follicles with which they are connected, whilst they retract or depress the intermediate cutaneous tissue; and this condition of the skin may be produced locally by the electric stimulus applied by means of the magneto-electric apparatus. The scrotum, as is well known, becomes shrunk and corrugated by the application of cold or mechanical irritation to its surface; but in this case the contraction takes place in the subcutaneous tissue, and the skin is puckered.

Reproduction of skin.—When a considerable portion of the skin is lost, the breach is repaired partly by a drawing inwards of the adjoining skin, and partly by the formation of a dense tissue, less vascular than the natural corium, and in which, so far as I know, hairs and glands are not reproduced, so that some deny that the cutaneous tissue is regenerated. Still the new part becomes covered with epidermis, and its substance sufficiently resembles that of the corium to warrant its being considered as cutaneous tissue regenerated in a simple form. I may add, that in small breaches of continuity from cuts inflicted in early life, the uniting part sometimes acquires furrows similar to those of the adjoining surface.

SECRETING GLANDS.

The term gland has been applied to various objects, differing widely from

hair follicles were infested by a worm, which he has described and delineated in Müller's Archiv. for 1842. Since then, further interesting details respecting this curious parasite, with observations on its development, have been contributed by Mr. E. Wilson. Phil. Trans. 1844.

each other in nature and office, but the organs of which it is proposed to consider generally the structure in the present chapter, are those devoted to the function of secretion.

By secretion is meant a process in an organised body, by which various matters, derived from the organism, are collected and discharged at particular parts, in order to be further employed for special purposes in the economy, or to be simply eliminated as redundant material or waste products. Of the former case, the saliva and gastric juice, and of the latter, which by way of distinction is often called "excretion," the urine and sweat may be taken as examples.

Secretion is very closely allied to nutrition. In the one process, as in the other, materials are selected from the general mass of blood and appropriated by textures and organs; but in the function of nutrition or assimilation, the appropriated matter is destined, for a time, to constitute part of the texture or organ, whereas in secretion it is immediately discharged at a free surface. The resemblance is most striking in those cases in which the waste particles of the texture nourished are shed or cast off at its surface, as in the cuticle and other epithelial tissues.

In man, and in animals which possess a circulating blood, that fluid is the source whence the constituents of the secretions are proximately derived; and it is further ascertained, that some secreted matters exist ready formed in the blood, and require only to be *selected* and separated from the general mass, whilst others would seem to be *prepared* from the materials of the blood, by the agency of the secreting organ. Among the secreted substances belonging to the former category, several, such as water, common salt, and albumen, are primary constituents of the blood, but others, as urea, uric acid, and certain salts, are the result of changes, both formative and destructive, which take place in the solid textures and in the blood itself, in the general process of nutrition. Again, as regards those ingredients of the secretions which are prepared or elaborated in the secretory apparatus, it is to be observed, that the crude material may undergo changes in organic form, as well as in chemical composition. Evidence of this is afforded by the solid corpuscles found in many secretions, as well as by the seminal cells and spermatozoa produced in the testicle.

In the structural adaptations of a secreting apparatus, it is in the first place provided that the blood-vessels approach some free surface from which the secretion is poured out. The vessels, however, do not open upon the secreting surface, for their coats, as well as the tissue covering them, are permeable to liquids; and the most favourable conditions for the discharge of fluid are ensured by the division of the vessels into their finest or capillary branches, and by the arrangement of these capillaries in close order, as near as possible to the surface. In this way, their coats are reduced to the greatest degree of tenuity and simplicity, and the blood, being divided into minute streams, is extensively and thoroughly brought into contact with the permeable parietes of its containing channels, as well as effectually and, by reason of its slow motion, for a long time exposed to those influences, whether operating from within or without the vessels, which promote transudation.

Such a simple arrangement as that just indicated is sufficient for the separation of certain substances from the general mass of the blood; for the coats of the vessels and tissue superjacent to them are not permeated with equal facility by all its constituents; and in certain cases the elimination of

fluid in the animal body is effected without the necessary aid of any more complicated apparatus. Thus, the exhalation of carbonic acid and watery vapour from the interior of the lungs and air passages, is probably produced in this simple manner, although the structure of the exhaling membrane is, for other reasons, complex; and the discharge of fluid into cavities lined be serous membranes, which is known to be preternaturally increased by artificial or morbid obstruction in the veins, may be a case of the same kind.

But another element is almost always introduced into the secreting structure, and plays an important part in the secretory process; this is the nucleated cell. A series of these cells, which are usually of a spheroidal or polyhedral figure, is spread over the secreting surface, in form of an epithelium, which rests on a simple membrane, named the basement membrane, or membrana propria. This membrane, itself extravascular, limits and defines the vascular secreting surface; it supports and connects the cells by one of its surfaces, whilst the other is in contact with the blood-vessels, and it may very possibly, also, minister, in a certain degree, to the process of secretion, by allowing some constituents of the blood to pass through it more readily than others. But the cells are the great agents in selecting and preparing the special ingredients of the secretions. They attract and imbibe into their interior those substances which, already existing in the blood, require merely to be segregated from the common store and concentrated in the secretion, and they, in certain cases, convert the matters which they have selected into new chemical compounds, or lead them to assume organic structure. A cell thus charged with its selected or converted contents yields them up to be poured out with the rest of the secretion, the contained substance escaping from it either by exudation or, as is probably more common, by dehiscence of the cell-wall, which, of course, involves the destruction of the cell itself. Cells filled with secreted matter may also be detached, and carried out entire with the fluid part of the secretion; and, in all cases, new cells speedily take the place of those which have served their office. The fluid effused from the blood-vessels, no doubt, supplies matter for the nutrition of the secreting structure, besides affording the materials of the secretion, the residue, when there is any, being absorbed.

Examples, illustrative of the secreting agency of cells, are afforded both by plants and animals. Thus, cells, are found in the liver of various animals, and especially of crustaceans and mollusks, some of which contain a substance resembling coloured biliary matter, and others particles of fat. Also, in the urinary organ of mollusks, cells are seen which inclose little opaque masses of uric acid. The secretion of the sebaceous follicles in man often contains detached cells filled with fat; and, according to Mr. Goodsir's observation, the ink-bag of the cuttle-fish is lined with an epithelium, the constituent cells of which are charged with pigment, similar to that which imparts the dark colour to the inky secretion. This last instance, as well as the production of spermatozoa, is an example of the formation of new products within secreting cells, a process further illustrated in plants, which afford abundant and decided evidence of the production of young cells, spermatic filaments, starch-granules, oil, various colouring matters, and other new compounds, in the interior of cells.

Both in animals and plants, the individual cells which are associated together on the same secreting surface may differ from each other in the nature of their contents. Thus, in the liver of mollusca some cells con-

tain biliary matter, and others contain fat; and in the recent soft part of the epidermis and its appendages, it is quite common to see cells filled with pigment mixed with others which are colourless.

A secreting apparatus, effectual for the purpose which it is essentially destined to fulfil, may thus be said substantially to consist of a simple membrane, named the membrana propria or basement membrane (marked *a* in the plan, fig. CXXVI.), supporting a layer of secreting cells on one of its surfaces (indicated by the dotted line *b*, in the figure), whilst finely-ramified blood-vessels are spread over the other (*c*). But whilst the structure may remain essentially the same, the configuration of the secreting surface, or (what amounts to the same thing) of the supporting basement membrane, presents various modifications in different secreting organs. In some cases, the secreting surface is plain, or, at least, expanded, as in various parts of the serous, synovial, and mucous membranes, which may be looked on as

Fig. CXXVI.

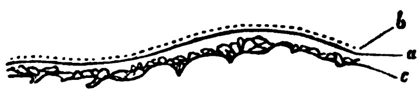


Fig. CXXVI.—Plan of a Secreting Membrane.

a, membrana propria or basement membrane; *b*, epithelium, composed of secreting nucleated cells; *c*, layer of capillary blood-vessels.

examples of comparatively simple forms of secreting apparatus; but, in other instances, and particularly in the special secretory organs named glands, the surface of the secreting membrane is variously involved and complicated. An obvious, and no doubt a principal, purpose of this complication is to increase the extent of the secreting surface in a secreting organ, and thus augment the quantity of secretion yielded by it. No connection has been clearly shown to exist between the *quality* of the secretion and the particular configuration, either internal or external, of the organ; on the other hand, we know that the same kind of secretion that is derived from a complex organ in one animal, may be produced by an apparatus of most simple form in another.

The more immediate purpose of the complication of the secreting membrane being to augment its surface within a comparatively circumscribed space, two principal modes are found by which the membrane is so increased in extent, namely, by rising or protruding, in form of a prominent fold or some otherwise shaped projection (fig. CXXVII., *d*, *e*), or by retiring, in form of a recess (fig. CXXVIII., *g*, *h*).

The first-mentioned mode of increase, or that by *protrusion*, is not what is most generally followed in nature, still it is not without example, and, as instances, we may cite the Haversian fringes of the synovial membranes, the urinary organ of the snail, which is formed of membranous lamellæ, and perhaps, also, the choroid plexuses in the brain, and the ciliary processes in the eye-ball, although secretion may not be the primary office of the last-mentioned structures. In most of these cases, the membrane assumes the form of projecting folds, which, for the sake of further increase of surface, may be again plaited and complicated, or cleft and fringed, at their borders (fig. CXXVII., *e*, *f*).

The plan of augmenting the secreting surface by *recession* or *inversion* of the membrane, in form of a cavity, is, with few exceptions, that generally

adopted in the construction of secreting glands. The first degree is represented by a simple recess (fig. CXXVIII., *g*, *h*), and such a recess, formed of

Fig. CXXVII.

Fig. CXXVII.—Plan to Show Augmentation of Surface by Formation of Processes.

a, *b*, *c*, as in preceding figure; *d*, simple, and *e f*, branched or subdivided processes.

secreting membrane, constitutes a *simple* gland. The shape of the cavity may be tubular (*g*) or saccular (*h*), and, in either case, it is called indifferently a *crypt*, *follicle*, or *lacuna*, for these names have not been strictly distinguished in their application. Examples of these simple glands are found in the mucous membrane of the stomach, intestines, and uterus. The secreting surface may be increased, in a simple tubular gland, by mere lengthening of the tube, in which case, however, when it acquires considerable length, the tube is coiled up into a ball (fig. CXXVIII., *i*), so as to take up less room, and adapt itself to receive compactly ramified blood-vessels. The sweat-glands, already described, and the ceruminous glands of the ear are instances of simple glands formed of a long convoluted tube. But the great means adopted for further increasing the secreting surface is by the subdivision, as well as extension, of the cavity, and when this occurs the gland is said to be *compound*. There is, however, a condition which might be looked on as a step between the simple and compound glands, in which the sides or extremity of a simple tube or sac become pouched or loculated (fig. CXXVIII., *k*, *l*). This form might be named the *multilocular crypt*.

In the compound glands, the divisions of the secreting cavity may assume a tubular or a saccular form, and this leads to the distinction of these glands into the "tubular," and the "saccular," or "racemose."

The *racemose* compound glands (fig. CXXVIII. C) contain a multitude of saccules, opening in clusters, into the extremities of a branched tube, named the excretory duct. The saccules are rounded, pyriform or thimble shaped, and then often named "cæcal." They are, as usual, formed by a proper or basement membrane, and lined, or often rather filled, with secreting cells; they are arranged in groups, round the commencing branches of the duct, into which they open both terminally and laterally (fig. CXXVIII. C, *n*); or it might with equal truth be said that the branches of the duct are distended into clusters of saccular dilatations. The ultimate branches of the duct open into larger branches (*o*), these into larger again, till they eventually terminate in one or more principal excretory ducts (*m*), by which the secretion is poured out of the gland. It is from the clustered arrangement of their ultimate vesicular recesses that these glands are named "racemose" (in German "traubenförmige Drüsen"); and they, for the most part, have a distinctly lobular structure. The lobules are held together by the branches of the duct to which they are appended, and by interlobular connective tissue which also supports the blood-vessels in their ramifications. The larger lobules are made up of smaller ones, these of still smaller, and so on, for several successions. The

smallest lobules (n) consist of two or three groups of saccules, with a like number of ducts, joining into an immediately larger ramuscule (o), which issues from the lobule; and a collection of the smallest lobules, united by

Fig. CXXVIII.

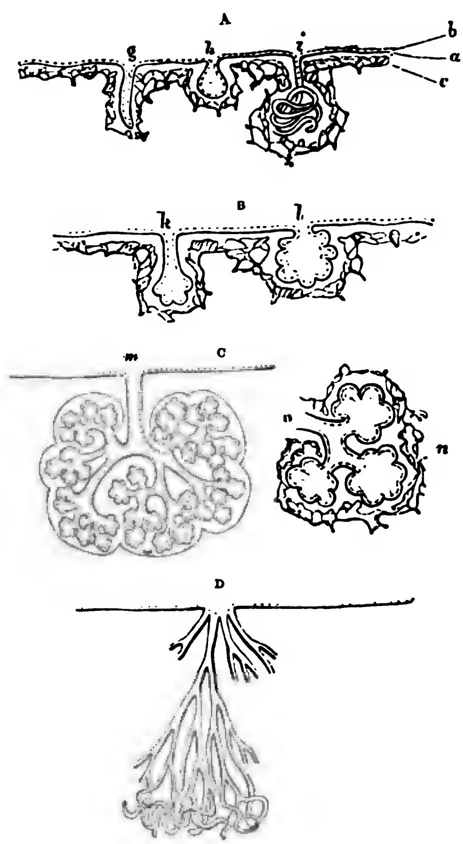


Fig. CXXVIII.—Plans of Extension of Secreting Membrane, by Inversion or Recession in Form of Cavities.

A, simple glands, viz., g, straight tube; h, sac; i, coiled tube. B, multilocular crypts; k, of tubular form; l, saccular. C, racemose, or saccular compound gland; m, entire gland, showing branched duct and lobular structure; n, a lobule, detached with o, branch of duct proceeding from it. D, compound tubular gland.

connective tissue and vessels, forms one of the next size, which, too, has its larger branch of the duct, formed by the junction of the ramuli belonging to the ultimate lobules. In this way, the whole gland is successively made up, the number of its lobules and of the branches of its duct depending on its size; for whilst some glands of this kind, like the parotid and pancreas, consist of innumerable lobules, connected by a large and many-branched duct, others, such as the duodenal glands of Brunner and many mucous glands, are formed of but two or three ultimate lobules, or

even of a single one, with a duct, minute in size and sparingly branched, to correspond. In fact, a small racemose gland resembles a fragment of a larger one.

A great many compound glands, yielding very different secretions, belong to the racemose class. As examples, it will be sufficient to mention the pancreas, the salivary, lachrymal, and mammary glands, with the glands of Brunner already referred to, and most of the small glands which open into the mouth, fauces, and windpipe. From the description given of their structure, it will be understood why the term "conglomerate glands" has been applied especially, though not exclusively, to this class. Their smallest lobules were called *acini*, a term which has also been used to denote the saccular recesses in the lobules, and indeed the word *acinus*, which originally meant the seed of a berry or the stone of a grape, or sometimes the grape itself, has been so vaguely applied by anatomists, that it seems better to discard it altogether.

Of the *tubular* compound glands, the most characteristic examples are the testicle and kidney. In these the tubular ducts divide again and again into branches, which, retaining their tubular form, are greatly lengthened out. The branches of the ducts are, as usual, formed of a limitary or basement membrane (*membrana propria*), lined by epithelium, and in contact, by its opposite surface, with capillary blood-vessels. By the multiplication and elongation of the tubular branches a vast extent of secreting surface is obtained, whilst, to save room, the tubes are coiled up into a more or less compact mass, which is traversed and held together by blood-vessels, and sometimes, also, divided into lobules and supported, as in the testicle, by fibrous partitions, derived from the inclosing capsule of the gland. In consequence of their intricately involved arrangement, it is difficult to find out how the tubular ducts are disposed at their extremities. It seems probable, however, that some are free, and simply closed without dilatation, and that others anastomose with neighbouring tubes, joining with them in form of loops; in the kidney, little round tufts of fine blood-vessels project into terminal or lateral dilatations of the ducts, but without opening into them.

The human liver does not precisely agree in structure with either of the above classes of compound glands. Its ducts, which are neither coiled nor sacculated, would seem to begin within its lobules, in form of a network occupying the interstices of the reticular capillary blood-vessels, which also are peculiar, inasmuch as they receive and transmit venous blood.

Lastly, there are certain little bodies of doubtful nature, connected with the mucous membrane of the intestines, and known as the solitary and the agminated glands, which differ from all those hitherto spoken of, inasmuch as they are small saccules without an opening. Some anatomists are of opinion that they discharge their contents, from time to time, by bursting; whilst others, without denying the possibility of this, are disposed to take a different view of these glandular bodies, and (as, at any rate there are no ducts) refer them to the class of "ductless glands," under which head they will be again adverted to. The full description of these glands, as well as of the peculiarities in the structure of the liver and kidney above referred to, belongs to the details of special anatomy.

Besides blood-vessels, the glands are furnished with lymphatics, which in the compound glands proceed from lacunar lymphatic spaces within, as already stated (p. clxxxiii.). Branches of nerves have also been followed, for some way, into these organs, and the well-known fact, that the flow of

secretion in several glands is affected by mental emotions, shows that an influence is exerted on secreting organs through the medium of the nervous system; and this is further shown by the fact, now ascertained, that an increased flow may be brought on by direct or reflex stimulation of their nerves. The distribution of these nerves in the salivary glands has been recently traced by Pflüger. He finds that dark-bordered nerve-fibres proceed to the cæcal grandular saccules; that the membranous tube of the nerve-fibre becomes continuous with the membrana propria of the saccule, whilst the fibre, retaining its dark borders, passes into the saccule and divides into fine branches, which run between the nucleated gland-cells lining it, and finally penetrate the walls of these cells and become connected with their nuclei. Other nerve fibres proceeding to the saccules come from ganglionic or nerve-cells; these fibres are chiefly pale or non-medullated, though not without admixture of the dark bordered kind, and are supposed to belong to the sympathetic system. These ganglionic fibres have also been traced to the gland-cells.

From what has been stated, it will be apparent that the substance of a gland consists of the ducts, blood-vessels, lymph-lacunæ, and a few nerves, in some cases connected by an intervening tissue. In the testicle there is a very small amount of intermediate connective tissue, which, with the aid of the blood-vessels, holds the tubules but feebly together, so that the structure is comparatively loose, and readily admits of being teazed out; but then it is sufficiently protected and supported by a fibrous capsule on the outside, and fibrous septa within the gland. In the racemose glands there is a good deal of uniting connective tissue, which surrounds collectively each group of saccules, binds together the lobules, and supports the vessels in their ramifications. The substance of the kidney contains scarcely any well characterised fibrous connective tissue, except bundles which here and there accompany the larger branches of vessels, but there is an abundant, though very delicate, network of retiform tissue in a soft, amorphous matter between the tubules and blood-vessels, which binds them together.

Parenchyma is a term sometimes employed in describing glandular organs, though it is less in use now than formerly. It is used sometimes to denote the solid part of a gland composed of the various tissues already mentioned; at other times to signify any substance, of whatever nature, lying between the ducts, vessels, and nerves. In this last sense, the parenchyma is in certain glands represented by connective tissue, in others by corpuscles and amorphous matter, whilst in some it can scarcely be said to exist.

Some glands have a special envelope, as in the case of the kidney and testicle; others, as the pancreas, have none.

The ducts of glands ultimately open into cavities lined by mucous membrane, or upon the surface of the skin. They are sometimes provided with a reservoir, in which the secretion is collected, to be discharged when the purposes of the economy so demand. The reservoir of the urine receives the whole of the secreted fluid; in the gall-bladder, on the other hand, only a part of the bile is collected. The vesiculæ seminales afford another example of these laterally appended reservoirs. The ducts are constructed of a basement membrane and lining of epithelium, and in their smaller divisions there is nothing more; but in the larger branches and trunks a fibro-vascular layer is added, as in the ordinary mucous membrane, with which many of them are continuous, and with which they all agree in nature. A more or less firm outer coat, composed of connective tissue, comes, in many cases, to surround the mucous lining, and between the two,

or, at any rate, outside the mucous coat, there is in some ducts a deposit of non-striated muscular tissue. The epithelium is usually composed of spheroidal or polyhedral cells at the commencement of the ducts, and is columnar in the rest of their length, though sometimes flattened or scaly, as in the mammary gland.

DUCTLESS OR VASCULAR GLANDS.

There are certain bodies which have received the name of glands on account of their resemblance in general appearance and structure to the ordinary secreting organs. They differ, however, from the latter in the fact of their possessing no ducts for the discharge of secretion ; so that the products of secretive action, if finding any outlet, are compelled to do so by rupture, by filtration through the tissues, or by re-absorption into the circulating current. The bodies in question have been termed "ductless" for this obvious anatomical reason : and "vascular," on certain physiological or theoretic grounds, as they are supposed to effect some change in the blood which is transmitted through them.

To this class belong the following bodies :—the spleen, the thyroid body, thymus gland, supra-renal capsules, pituitary body ; and, according to various authorities, we ought to place in the same category the solitary closed follicles of the stomach and intestines, the Peyerian glands, the follicular glands at the root of the tongue, and also the lymphatic glands. The peculiar structure of each of these organs (except the lymphatic glands, already treated of) will be considered in its proper place in that portion of this work which is devoted to special anatomy ; and we have here to give only a general outline of those structural provisions which are, with more or less modification, common to them all.

The following may be taken as a general account of the mode in which their constituent elements are arranged. The form of the gland is determined by a fibrous, and in some instances dense and firm, investing membrane, which in the larger organs is furnished with prolongations projecting inwards as septa, giving considerable firmness to the texture, and either forming loculi or rounded cavities within them, or merely leaving spaces between the septa, in which the peculiar substance of the gland is placed. The investing membrane consists of both white and elastic fibres, in varying proportion, and, in many instances in the lower animals, of non-striated muscular fibres. Each gland is abundantly supplied with blood-vessels, both arterial and venous ; the former commonly dividing frequently, but entering into no anastomosis until they have arrived at their ultimate ramification in a capillary plexus ; the latter (the veins) are usually large, valveless, and in some situations appear dilated into sacs ; but this appearance has been questioned. Lymphatic vessels, proceeding from lacunæ within the gland, and nerves exist in very varying proportions.

The blood-vessels as they pass through these glands are in some cases closely surrounded by a peculiar pulpy substance, varying in amount and colour at different periods, but generally existing in considerable quantity. This pulp consists of corpuscles, granular matter, and fat-molecules. The corpuscles are of very different kinds and vary widely in size ; some, and those are the best established, resemble lymph, chyle, or pale blood-corpuscles ; others, free nuclei ; some, of more questionable existence, are said to be large compound cells, containing in their interior globules closely

resembling those of the blood; others are described as containing many nuclei, and much granular matter.

These being the general characters of the ductless glands, the varieties met with in the human body may be arranged as follows :—

a. Rounded and closed capsules filled with nucleated cells, nuclei, and intercellular fluid, and traversed by blood-capillaries; the capsules placed singly or in flat patches under a mucous membrane (solitary and agminated intestinal glands), or surrounding a simple or complex recess lined by and opening on the surface of a mucous membrane (certain lingual and pharyngeal glands, and tonsils); it being uncertain whether the contents of the capsules are discharged by rupture or transudation, or taken up by absorption.

b. A lobulated organ inclosing a sinuous internal cavity, with no outlet, filled with a liquid secretion containing corpuscles; the cavity branching into the lobules, and ending in the smallest of them, according to one opinion, by groups of saccular dilatations of its membrana propria, covered outwardly by capillary blood-vessels, as in the racemose secreting glands. According to another view the walls of the cavity in an ultimate lobule are not set round with saccules, but with small solid pellets, formed of aggregated corpuscles similar to those of the fluid, and bounded towards the outer surface of the lobule by a membrana propria, *within* which is a group of blood-vessels pervading the corpuscular matter, as in *a*, (thymus).

c. A glandular body containing different-sized locular spaces formed by a stroma of fibrous or more or less homogeneous connective tissue: the loculi containing granules, nuclei, and nucleated cells of various sizes, with intercellular fluid (anterior lobe of the pituitary body and supra-renal capsules), or lined by a membrana propria and epithelium, and filled with clear tenacious fluid (thyroid body).

d. An organ containing a peculiar pulp lodged in the interstices of a trabecular and highly vascular structure; also capsules with contents as in *a*, attached to the vessels, and surrounded by the pulp, which, while containing collections of red blood-corpuscles in various conditions, resembles generally in nature the matter within the capsules, and is likewise traversed by fine blood-vessels (spleen).

e. Rounded or oval bodies having in their interior intercommunicating loculi and intertrabecular spaces, further subdivided by retiform tissue, and partially occupied by a corpuscular gland-pulp traversed by blood-capillaries; everywhere round the pulp a space left for the passage of lymph, communicating with the afferent and efferent lymphatics (lymphatic glands).

The purposes fulfilled by most of the organs referred to are still involved in great obscurity, and very different opinions are held on the subject by eminent authorities in Physiology.

IV. ORGANS OF THE SENSES.

In this place it is intended to describe the organs of sight, hearing and smelling, which, considered with reference to their anatomy and development, are regarded as the higher organs of special sense. The description of the organ of touch is given along with the skin in the histological part of the work, and that of the organ of taste along with the descriptive anatomy of the digestive system.

THE EYE.

The organ of vision, strictly speaking, consists only of the ball or globe of the eye, a spheroidal structure enclosed by strong membranous coverings, receiving the optic nerve posteriorly, and containing the sensitive terminations of that nerve, together with a series of transparent media, which constitute an optical instrument of variable focus, through which the rays of light are transmitted to the sensitive part, and so brought into focus as to form upon it a distinct inverted image of the objects from which they proceed. But there are likewise various structures external to the eyeball which contribute to the production of perfect vision, such as the straight and oblique muscles by which the eyeball is moved in different directions, and the various supporting and protective structures known as *appendages of the eye* (tutamina oculi), including the eyebrows, eyelids, and conjunctiva, and the lachrymal apparatus.

APPENDAGES OF THE EYE.

THE EYELIDS AND CONJUNCTIVA.

The eyelids (palpebræ) are moveable folds of integument, strengthened toward their margins by a thin lamina of cartilage. The mucous membrane, which lines their inner surface, and which is reflected thence in the form of a pellucid covering on the surface of the eyeball, is named membrana conjunctiva.

The upper lid is larger and more moveable than the lower: the transparent part of the globe is covered by it when the eye is closed; and the eye is opened chiefly by the elevation of this lid by a muscle (levator palpebræ) devoted exclusively to this purpose. The eyelids are joined at the outer and inner angles (canthi) of the eye. The interval between the angles, *fissura palpebrarum*, varies in length in different persons, and, according to its extent, the size of the globe being nearly the same, gives the appearance of a larger or a smaller eye. The greater part of the edge of each eyelid is flattened, but towards the inner angle it is rounded off for a short space, at the same time that it somewhat changes its direction; and, where the two differently formed parts join, there exists on each lid a slight conical elevation—*papilla lachrymalis*, the apex of which is pierced by the aperture or punctum of the corresponding lachrymal canalicule.

In the greater part of their extent the lids are applied to the surface of the eyeball; but at the inner canthus, opposite the puncta lachrymalia, there intervenes a vertical fold of conjunctiva, the *plica semilunaris*, resting on the eyeball; while, occupying the recess of the angle internal to the border of this fold, is a spongy-looking reddish elevation, formed by a group

of glandular follicles, and named the *caruncula lachrymalis.* The plica semilunaris is the rudiment of the third eyelid (membrana nictitans) found in some animals.

Structure of the lids.—The skin covering the eyelids is thin and delicate; and at the line of the eyelashes, altered in its character, it joins the conjunctival mucous membrane which lines the inner surface of the lids. Beneath the skin, and between it and the conjunctiva, the following structures are successively met with, viz.:—The fibres of the orbicularis muscle; loose connective tissue; the tarsal cartilages, together with a thin fibrous membrane, the palpebral ligament, which attaches them to the margin of the orbit; and, finally, the Meibomian glands. In the upper eyelid there is, in addition, the insertion of the levator palpebræ superioris, in the form of a fibrous expansion fixed to the anterior surface of the tarsal cartilage.

Fig. 456.

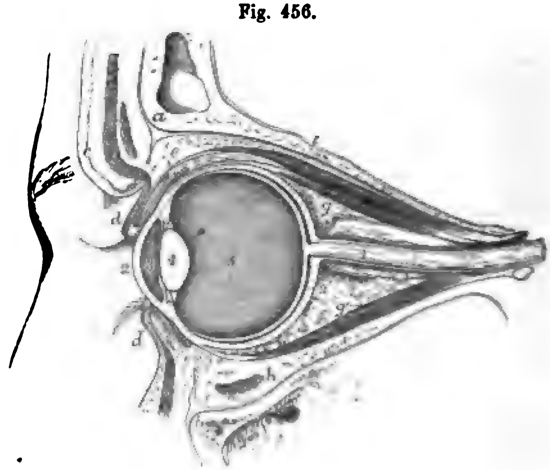


Fig. 456.—Vertical Section of the Left Orbit and its Contents.

The section has been carried through the middle of the optic foramen and optic nerve obliquely as far as the back of the eyeball, and thence forward through the eyeball, eyelids, &c., in an antero-posterior direction. *a*, the frontal bone; *b*, the superior maxillary bone; *c*, the eyebrow with the orbicularis palpebrarum, integument, &c., divided; *d*, the upper, and *d'*, the lower eyelid, partially open, showing the section of the tarsal cartilages and other component parts, the eyelashes, &c.; *e*, *e*, the reflection of the conjunctiva from the upper and lower eyelids to the surface of the eyeball; *f*, the levator palpebræ superioris muscle; *g*, the upper, *g'*, the lower rectus muscle; *h*, the inferior oblique muscle divided; 1, 1, the optic nerve divided in its sheath; 2, the cornea; 2', the sclerotic; 3, the aqueous chamber; 4, the crystalline lens; 5, the centre of the vitreous humour.

The *fibres of the orbicularis muscle* are closely adherent to the skin by fine connective tissue, entirely devoid of fat. A marginal fasciculus of its fibres has been found within the line of the eyelashes, separated by the bulbs of the lashes from the other fibres, and constituting the *ciliary muscle* of Riolan. The fibres of the orbicular muscle, while adherent to the skin, glide loosely on the tarsal cartilages.

The *tarsal cartilages* (tarsi) are two thin elongated plates of cartilage of the yellow kind placed one in each lid, and serving to give shape and firmness to those parts. The upper cartilage, the larger, is half oval in form,

being broader near the centre and narrowing towards the angles of the lids. The lower is thinner, much narrower, and more nearly of a uniform breadth throughout. The free or ciliary edge of the cartilages, which is straight, is thicker than any other part. At the inner canthus the cartilages are fixed by the fibrous slips of the tendo palpebrarum (p. 172); and at the outer angle they are attached to the malar bone by a fibrous band belonging to the palpebral ligament, and named the external *tarsal ligament.*

The *palpebral ligament* is a fibrous membrane placed beneath the orbicularis muscle, attached peripherally to the margin of the orbit, and internally to the tarsal cartilages near the inner free edge. The membrane is thickest at the outer part of the orbit.

Meibomian glands.—On the ocular surface of each lid are seen from twenty to thirty parallel vertical lines of yellow granules, lying immediately under the conjunctival mucous membrane. They are compound sebaceous follicles, embedded in grooves at the back of the tarsal cartilages; and they open on the free margin of the lids by minute orifices, generally as many in number as the lines of follicles themselves. These glands consist of nearly straight excretory tubes, each of which is closed at the end, and has numerous small cæcal appendages projecting from its sides. The tubes are lined by mucous membrane, on the surface of which is a layer of scaly or pavement epithelium cells.

Fig. 457.

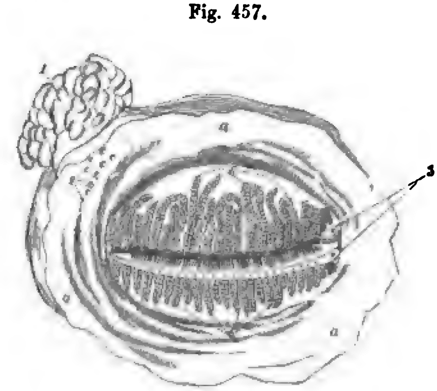


Fig. 457.—MEIBOMIAN GLANDS, LACHRYMAL GLAND, &c., AS SEEN FROM THE DEEP SURFACE OF THE EYELIDS OF THE LEFT SIDE.

a, palpebral conjunctiva; 1, lachrymal gland; 2, openings of seven or eight glandular ducts; 3, upper and lower puncta lachrymalia; 6, 6, shut ends of the upper and lower Meibomian glands, of which the openings are indicated along the margins of the eyelids.

According to Heinrich Müller there is likewise a layer of unstriped muscular fibre contained in each eyelid; that of the upper lid arising from the under surface of the levator palpebræ, that of the lower lid arising from the neighbourhood of the inferior oblique muscle, and each being inserted near the margin of the tarsal cartilage. It may also be mentioned in this place that the same writer describes a layer of unstriped muscle crossing the spheno-maxillary fissure, corresponding to a more largely developed layer found in the extensive aponeurotic part of the orbital wall of various mammalia. This set of fibres has been more particularly described by Turner (H. Müller, in Zeitschr. f. Wiss. Zool. 1858, p. 541; W. Turner, in Nat. Hist. Rev. 1862, p. 106).

The *eyelashes* (cilia) are strong short curved hairs, arranged in two or more rows along the margin of the lids, at the line of union between the skin and the conjunctival mucous membrane. The lashes of the upper lid, more numerous and longer than the lower, have the convexity of their curve directed downwards and forwards; whilst those of the lower lid are arched in the opposite direction. Near the inner canthus these hairs are weaker and more scattered.

Structure of the conjunctiva.—The conjunctiva consists of the palpebral part, along with which may be grouped the plica semilunaris and caruncula lachrymalis, and of the ocular part or conjunctiva bulbi, in which may be distinguished the sclerotic and corneal portions : each of these several parts presents peculiar and distinctive characters. The epithelium is stratified and thick; the cells of the superficial strata scaly, delicate, and each with a distinct nucleus.

The *palpebral portion* of the conjunctiva is opaque and red, is thicker and more vascular than any other part of the membrane, and presents numerous fine papillæ freely supplied with nerves. At the margins of the lids the palpebral conjunctiva enters the ducts of the Meibomian glands; through the puncta lachrymalia it passes into the canaliculi, and is continuous with the lining membrane of the lachrymal sac ; and it is prolonged into the orifices of the ducts of the lachrymal gland.

The *sclerotic portion* of the conjunctiva, changing its character at the line of reflection from the eyelids, becomes thinner, and loses its papillary structure : it is loosely connected to the eyeball by submucous tissue. It is also transparent and nearly colourless, but a few scattered branches of blood-vessels are generally visible on it in the healthy condition, and under the influence of inflammatory congestion a copious network of vessels very irregularly disposed comes into view. This network is derived from the palpebral and lachrymal arteries. It may be easily made to glide loosely on the surface of the eyeball by pressing the eyelid against it. But another set of vessels likewise exists on the surface of the sclerotic, and may be brought into view by congestion. The position of this set is entirely sub-conjunctival, adherent to the sclerotic coat; they are less tortuous than the conjunctival set, and are derived from the muscular and anterior ciliary branches of the ophthalmic artery : they remain immoveable on pressure of the eyelid. They dip into the sclerotic near the cornea, and appear to unite with a more deeply connected minute network disposed in closely set straight lines, radiating from the margin of the cornea, and the gorged condition of which is well known to ophthalmic surgeons as characteristic of sclerotitis.

The *corneal conjunctiva* consists almost entirely of epithelium, any underlying membrane being extremely thin, transparent, and adherent to the anterior elastic layer of the cornea, in connection with which it will be again referred to. Vessels lie between it and the cornea, and form a circle of anastomotic capillary loops around the circumference. This plexus of vessels extends farther inwards in the fœtus.

A well developed network of *lymphatics* exists throughout the sclerotic and palpebral portions of the conjunctiva; but at the margin of the cornea a sudden diminution takes place in the size of the meshes and diameter of the vessels. Of the network referred to, only a narrow circle $\frac{1}{25}$th of an inch in diameter exists on the corneal conjunctiva, and this circle has a well defined inner margin within which no lymphatics exist (Teichmann).

The *nerves* in the membrane, as far as the cornea, seem to have the same arrangement as in the skin in general.

In the submucous tissue of the eyelids there are small follicular glands spread over the whole surface of the conjunctiva palpebrarum, and in the vicinity of the reflection of the conjunctiva upon the eyeball a set of larger more complex glands of a racemose structure, somewhat similar to that of the lachrymal gland (Sappey, C. and W. Krause).

Closed follicles have also been observed in the conjunctiva by Bruch, and, after him, by other observers.

THE LACHRYMAL APPARATUS.

The parts which constitute the lachrymal apparatus are the following, viz.:—The gland by which the tears are secreted, situated at the upper and outer side of the orbit, together with its excretory ducts; the two canals into which the fluid is received near the inner angle; and the sac with the nasal duct continued from it, through which the tears pass into the inferior meatus of the nose.

The *lachrymal gland*, an oblong flattened body, about the size of a small almond, is placed in the upper and outer part of the orbit, a little behind the anterior margin. The upper surface of the gland, convex, is lodged in a slight depression in the orbital plate of the frontal bone, to the periosteum of which it adheres by fibrous bands; the lower surface is adapted to the convexity of the eyeball, and is in contact with the upper and the outer recti muscles. The fore part of the gland, separated from the rest by a slight depression, and sometimes described as a second lobe, or as a distinct gland, is closely adherent to the back of the upper eyelid, and is covered on the ocular surface only by a reflection of the conjunctiva. The glandular ducts, usually from six to eight in number, are very small, and emerge from the thinner portion of the gland. After running obliquely under the mucous membrane, and separating at the same time from each other, they open in a row by separate orifices, the greater number in the fold above the outer canthus, and two of them (Hyrtl) in the fold below.

Fig. 458.

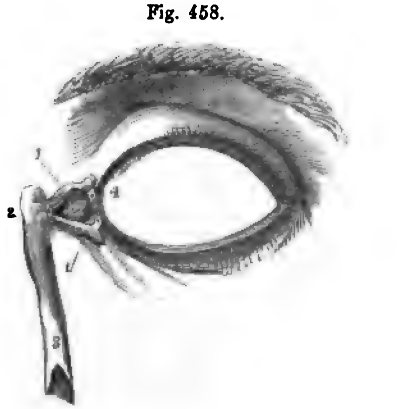


Fig. 458.—Front of the Left Eyelids, with the Lachrymal Canals and Nasal Duct exposed.

1, 1, upper and lower lachrymal canals, showing towards the eyelids the narrow bent portions and the puncta lachrymalia; 2, lachrymal sac; 3, the lower part of the nasal duct; 4, plica semilunaris; 5, caruncula lachrymalis.

Lachrymal canals.—On the margin of each lid, near the inner angle, and in front of the fold of membrane called plica semilunaris, is a small elevation (papilla lachrymalis), already described. Each papilla is perforated by a small aperture, *punctum lachrymale;* and at these apertures commence two small canals, *canaliculi*, which convey the tears from the eye to the lachrymal sac. The upper canal is rather the smaller and longer of the two: it first ascends from the punctum; then makes a sudden bend, and is directed inwards and downwards to join the lachrymal sac. The lower canal descends from the corresponding punctum; and soon changing its direction like the upper one, takes a nearly horizontal course inwards. Both canals are dilated where they are bent. In some cases they unite near the end to form a short common trunk; more commonly they open separately, but close together, into the sac.

The *lachrymal sac* and *nasal duct* constitute together the passage by which the tears are conveyed from the lachrymal canals to the cavity of the nose.

The lachrymal sac, the upper dilated portion of the passage, is situated at the side of the nose, near the inner canthus of the eye, and lies embedded in a deep groove in the ungual and upper maxillary bones. It is of an oval form; the upper end closed and rounded, and the lower end gradually narrowing somewhat into the nasal duct. On the outer side, and a little in front, it receives the lachrymal canals; and here it is covered by the tendo palpebrarum, and by some of the inner fibres of the orbicular muscle of the lids; while on its inner or posterior surface the tensor tarsi muscle is placed. The sac is composed of fibrous and elastic tissues, adhering closely to the bones above mentioned, and strengthened by fibrous processes sent from the tendo palpebrarum, which crosses a little above its middle. The inner surface is lined by a reddish mucous membrane, which is continuous through the canaliculi with the conjunctiva, and through the nasal duct with the mucous membrane of the nose.

The nasal duct (ductus ad nasum), about six or seven lines in length, grooving the upper maxillary bone, descends to the fore part of the lower meatus of the nose, the osseous canal being completed by the ungual and lower turbinated bones. A tube of fibrous membrane, continuous with the lachrymal sac, adheres to the parietes of this canal, and is lined by mucous membrane, which, at the opening into the nose, is often arranged in the form of an imperfect valve. The nasal duct is rather narrower in the middle than at either end; its direction is not quite vertical, but inclined slightly outwards and backwards.

The mucous membrane in the canaliculi possesses a laminar epithelium, but in the nasal sac and duct a ciliated epithelium as in the nose.

Various valves have been described in connection with the lachrymal sac and canals. One, the valve of Hasner, is formed by the mucous membrane of the nose overhanging the inferior orifice of the nasal duct, and has had imputed to it the function of preventing entrance of foreign matters in violent expiratory movements; but the disposition of the mucous membrane at this orifice appears to be subject to some variation. Another fold, the valve of Huschke, placed at the deep orifice of the canaliculi, is supposed by some to prevent the return of the tears from the sac into those tubes, but by others, it is declared to be inconstant, and insufficient, even when found, to close the orifice. A third fold, the valve of Foltz, is described as forming a projection inwards on one side of the vertical part of each canaliculus, near the punctum lachrymale, and as being sufficient to close the tube when it is flattened by the pressure of the fibres of the orbicularis and tensor tarsi muscles as in winking. The experiments of Foltz on rabbits go to prove that the punctum lachrymale having been turned backwards towards the eye in winking, and the canaliculus being compressed by the muscles, as soon as the pressure is removed the canaliculus resumes its open form, and so sucks in tears which by the next compression in winking are forced onwards into the lachrymal sac; and also, that when the muscles are paralysed, the canaliculi cease to carry away the tears. See review of Foltz's paper in Dublin Quarterly Journal, Feby. 1863; also, Hyrtl, Topogr. Anatomie.

THE GLOBE OF THE EYE.

The globe or ball of the eye is a composite structure of an irregularly spheroidal form, placed in the fore part of the orbital cavity, and receiving the thick stem of the optic nerve behind. The recti and obliqui muscles closely surround the greater part of the eyeball, and are capable of changing its position within certain limits: the lids, with the plica semilunaris and caruncle, are in contact with its covering of conjunctiva in front; and behind it is supported by a quantity of loose fat and connective tissue.

The eyeball, when viewed in profile, is found to be composed of segments of two spheres, of which the anterior is the smaller and more prominent: the segment of the larger posterior opaque sphere corresponds with the limit of the sclerotic coat, and the translucent portion of the smaller sphere with that of the cornea.

From before backwards the ball measures about nine-tenths of an inch, and its transverse diameter exceeds this measurement by about a line.

Except when directed towards near objects, the axes of the eyes are nearly parallel; the optic nerves, on the contrary, diverge considerably from one another, and each nerve enters the corresponding eye about a tenth of an inch to the inner or nasal side of the axis of the globe.

The eyeball is composed of several investing membranes, concentrically arranged, and of certain fluid and solid parts contained within them. The membranes are three in number, with the following designations and general structure:—An external fibrous covering, named *sclerotic* and *cornea*; a middle vascular, pigmentary, and in part also muscular membrane, the *choroid* and the *iris*; and an internal nervous stratum, the *retina*. The enclosed refracting media, three in number, are the *aqueous humour*, the *vitreous body*, and the *lens* with its *capsule*.

Around the eye-ball there is an adventitious tunic of fascia, *tunica vaginalis oculi*, or capsule of Tenon, which is perforated by the tendons of the recti and obliqui muscles, and connected with the sclerotic by merely the most delicate connective tissue. This capsule separates the eye-ball from the orbital fat, and enables it to glide freely in its movements. (See, for details, Richet, Traité d'Anatomie Médico-Chirurgicale; and O'Ferrall, in Dublin Quart. Journ. Med. Science, July, 1841.)

EXTERNAL COAT OF THE EYEBALL.

The external investing membrane, which forms a complete covering for the ball, consists of two parts of different appearance and structure. Of these the hinder part, much the largest, is opaque and densely fibrous, and is named the sclerotic coat, while the anterior smaller segment is transparent, and is named the cornea.

THE SCLEROTIC COAT.

The sclerotic (cornea opaca), the tunic of the eye on which the maintenance of the form of the greater part of the organ chiefly depends, is a strong, opaque, unyielding, fibrous structure. The membrane covers about five-sixths of the eye-ball, and is pierced behind by the optic nerve. The outer surface is white and smooth, except where the tendons of the recti and obliqui muscles are inserted into it. The inner surface is of a light brown colour, and rough from the presence of a delicate connective tissue (*membrana fusca*), through which branches of the ciliary vessels and nerves cross obliquely. The sclerotic is thickest at the back part of the eye, and thinnest at about a quarter of an inch from the cornea: at the junction with the cornea, it is again somewhat thickened. The optic nerve pierces this coat about one-tenth of an inch internal to the axis of the ball, and the opening is somewhat smaller at the inner than at the outer surface of the coat. The fibrous sheath of the nerve, together with the membranous processes which separate the funiculi of its fibres, blend with the sclerotic at the margin of the aperture: in consequence of this arrangement, when the nerve is cut off

close to the eye-ball, the funiculi are seen to enter by a group of pores; and to the part of the sclerotic thus perforated the name of *lamina cribrosa* is sometimes given. Around this cribrous opening are smaller apertures for vessels and nerves.

Fig. 459.

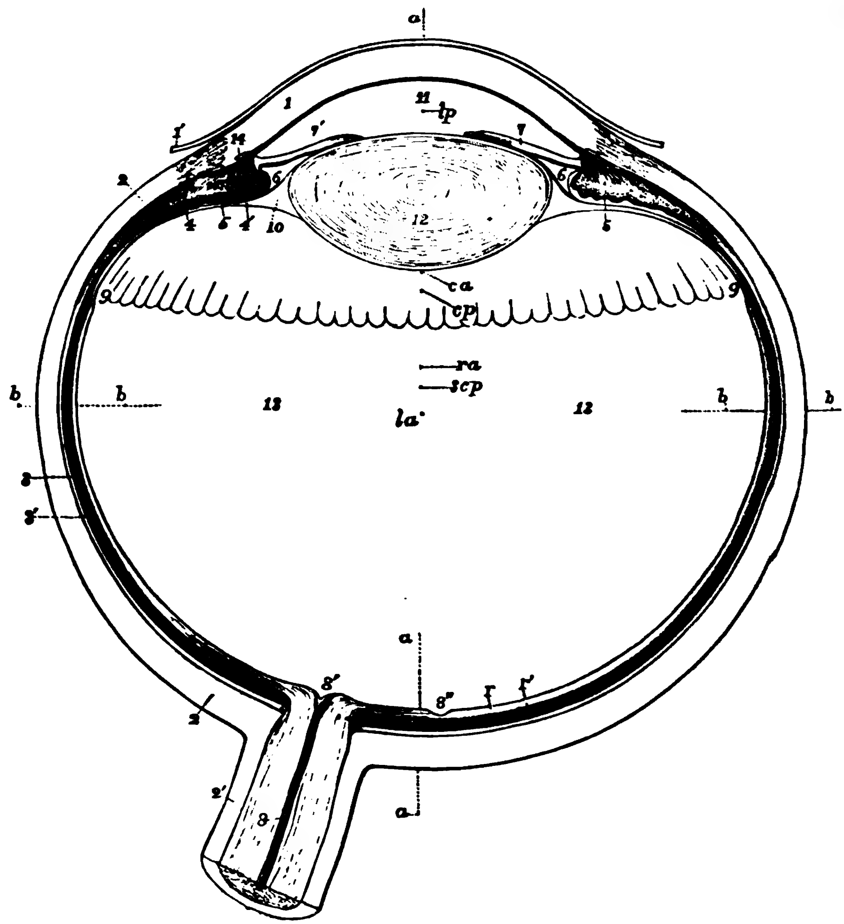


Fig. 459.—View of the Lower Half of the Right Adult Human Eye, divided horizontally through the middle. $\frac{4}{1}$

The specimen from which this outline is taken was obtained by dividing the eye of a man of about forty years of age in the frozen state. It was carefully compared with other specimens obtained in a similar manner; and in the drawing averages have been given in any particulars in which differences among them presented themselves.

1, the cornea; 1', its conjunctival layer; 2, the sclerotic; 2', sheath of the optic nerve passing into the sclerotic; 3, external or vascular layer of the choroid; 3', its internal pigmental layer; 4, ciliary muscle, its radiating portion; 4', cut fibres of the circular portion; 5, ciliary fold or process; 6, placed in the posterior division of the aqueous chamber, in front of the suspensory ligament of the lens; 7, the iris (outer side); 7', the smaller inner side; 8, placed on the divided optic nerve, points to the arteria centralis retinæ; 8', colliculus or eminence at the passage of the optic nerve into the

retina; 8″, fovea centralis retinæ; *r*, the nervous layer of the retina; *r′*, the bacillar layer; 9, ora serrata at the commencement of the ciliary part of the retina; 10, canal of Petit; 11, anterior division of the aqueous chamber in front of the pupil; 12, the crystalline lens, within its capsule; 13, the vitreous humour; *a*, *a*, *a*, parts of a dotted line in the axis of the eye; *b*, *b*, *b*, *b*, a line in the transverse diameter. It will be observed that from the pupil being placed nearer the inner side the axis of the eye-ball *a*, *a*, does not pass exactly through the centre of the pupil, and that this line falls a little to the inner side of the fovea centralis. The following letters indicate the centres of the curvatures of the different surfaces; assuming them to be nearly spherical, viz.: *ca*, anterior surface of the cornea; *cp*, posterior surface; *la*, anterior surface of the lens; *lp*, posterior surface; *scp*, posterior surface of the sclerotic; *ra*, anterior surface of the retina.

In connection with this figure the following average dimensions of the parts of the adult eye in fractions of an English inch may be stated:—

Transverse diameter of the eyeball	1·
Vertical diameter (Krause)	0·96
Antero-posterior diameter	0·96
Diameter of the optic nerve with its sheath	0·16
Diameter of the nervous part at its passage through the choroid membrane	0·09
Greatest thickness of the sclerotic, choroid, and retina together	0·08
Greatest thickness of the sclerotic posteriorly	0·05
Smallest thickness at the sides and in front	0·025
Greatest thickness of the cornea	0·055
Distance from the middle of the posterior surface of the cornea to the front of the lens	0·07
Antero-posterior diameter of the lens	0·19
Transverse ditto	0·35
Greatest thickness of the ciliary muscle and ciliary processes together	0·06
Greatest thickness of the ciliary muscle	0·035
Thickness of the iris	0·015
Length of the radius of curvature of the anterior surface of the cornea (regarding it approximately as spherical)	0·305
Radius of the posterior surface	0·275
Radius of curvature of the anterior surface of the lens	0·36
Radius of the posterior surface	0·21
Approximate length of the radius of curvature of the outer surface in the posterior half of the retina	0·485
Approximate radius of curvature of the external surface of the posterior part of the sclerotic coat	0·5
Distance of the middle of the posterior surface of the lens from the middle of the retina	0·575
Distance between the centre of the spot of entrance of the optic nerve and the middle of the fovea centralis retinæ	0·14
Diameter of the base of the cornea	0·48
Diameter of the base of the iris transversely	0·45
Diameter of the base of the iris vertically	0·43
Diameter of the pupil	0·14

STRUCTURE.—The sclerotic coat is formed of connective tissue, and yields gelatine on boiling. Its fibres are combined with fine elastic tissue, and with fusiform and stellate nucleated cells, and are aggregated into bundles, which are disposed in layers both longitudinally and transversely, the longitudinal arrangement being most marked at the surfaces. These layers communicate at intervals, and the sclerotic presents a ramified and laminar appearance on a vertical section.

A few blood-vessels permeate the fibrous texture in the form of a net-work of the smallest capillaries with very wide meshes; and in the neighbourhood of the cornea a ring of greater vascularity exists, which has been already noticed in the description of the sclerotic conjunctiva. The existence of nerves in the sclerotic has not yet been allowed by all anatomists.

THE CORNEA.

The cornea (cornea pellucida), the transparent fore part of the external coat, admits light into the interior of the ball. It is nearly circular in shape, and its arc extends to about one-sixth of the circumference of the whole globe; it is occasionally widest in the transverse direction. Being of a curvature of a smaller radius than the sclerotic, it projects forwards beyond the general surface of curvature of that membrane, somewhat like the glass of a watch: the degree of its curve varies, however, in different persons, and at different periods of life in the same person, being more prominent in youth and flattened in advanced age. Its thickness is in general nearly the same throughout, viz., from $\frac{1}{25}$ to $\frac{1}{32}$ of an inch, excepting towards the outer margin where it becomes somewhat thinner. The posterior concave surface exceeds slightly in extent the anterior or convex, in consequence of the latter being encroached on by the opacity of the sclerotic.

Fig. 460.

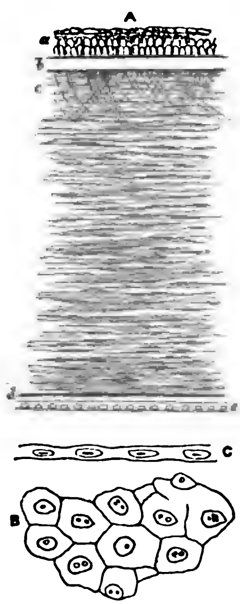


Fig. 461.

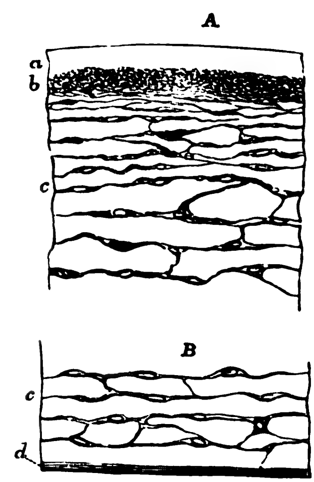


Fig. 460.—STRUCTURES OF THE CORNEA (after Bowman). A $\frac{80}{1}$, B & C, $\frac{300}{1}$

A, small portion of a vertical section of the cornea in the adult; *a*, conjunctival epithelium; *b*, anterior elastic lamina; *c* to *d*, fibrous laminæ with nuclear bodies interspersed between them; *c*, fibres shooting through some of these layers from the external elastic lamina; *d*, posterior elastic lamina; *e*, internal epithelium. B, epithelium of the membrane of Demours, as seen looking towards its surface. C, the same seen in section.

Fig. 461.—SMALL PORTIONS OF A VERTICAL SECTION OF THE CORNEA AT BIRTH (from Kölliker). $\frac{350}{1}$

The preparation has been treated with acetic acid. A, the anterior part; *a*, anterior elastic lamina; *b*, layer of closely set granules (probably small cells) placed under the anterior elastic layer, with little fibrous structure; *c*, developed fibrous tissue, with united connective-tissue corpuscles; B, posterior part of the cornea; *c*, as before; *d*, posterior elastic layer.

At its circumference the cornea joins the sclerotic part by continuity of tissue, but always so as to be overlapped by the opacity of that structure like a watch glass by the edge of the groove into which it is received.

STRUCTURE.—The cornea consists of a central thick fibrous part, the cornea proper, covered in front by the conjunctival epithelium and the anterior elastic lamina, and behind by the posterior elastic lamina or membrane of Demours.

The *cornea proper* is a stratified structure, the constituent fibres of which, continuous externally with those of the opaque sclerotic, are soft and comparatively indistinct, and between the strata of which are numerous delicate anastomosing nucleated cells, of fusiform appearance as seen in vertical sections, but expanded in the direction of the laminæ, and presenting in sections parallel to the surface a stellate appearance. The strata, about sixty in number, at a given spot (Bowman),* maintain frequent communications with contiguous layers, so that they can be detached only for a very short distance: in consequence of this stratified composition the cornea may be penetrated or torn most readily in the direction of the supposed laminæ. The transparency of the cornea is impaired by derangement of the relative position, or by approximation of the strata to each other. The cornea proper is permeable to fluid, and affords chondrin, not gelatine, on boiling (J. Müller).

There have been observed by v. Recklinghausen in the cornea of the frog, when examined in a chamber of liquid connected with the microscope, not only a rich network of anastomosing cells, but other cells also which change both their form and position by means of processes thrown out from and disappearing again into their substance, like the pseudopods of amœbæ. (Virchow's Archiv, Vol. 28, p. 157).

According to Henle, the anastomosing cells of the cornea are mere spaces devoid of any walls distinct from the surrounding matrix, and are the only interlaminar spaces naturally existing. (Systematische Anatomie, Vol. ii. p. 599).

The membranes investing the fibrous part of the cornea before and behind are both of them structureless, with epithelium on their free surface.

The anterior elastic lamina (Bowman) is a transparent glassy stratum without recognised texture, from $\frac{1}{3000}$th to $\frac{1}{1200}$th of an inch thick, and not rendered opaque by acids. From the surface resting on the fibrous strata of the cornea, a few fine threads are prolonged in a slanting direction, and are lost among the more superficial of those strata: their action is supposed to be to keep the membrane tied down smoothly to the cornea. The *epithelium* on the front of this lamina is stratified, the superficial cells being flat, and the main thickness formed of three or four layers of rounded cells, the deepest of which are vertically elongated, so as to be nearly twice as long as broad.

It is right to mention that this epithelium in the horse, the ox, and the sheep, has a much more remarkable appearance than in man, and one not to be accounted for by the ordinarily presumed mode of growth of stratified epithelia; for the deepest cells are greatly elongated and larger than those which are immediately superimposed, and have precisely the appearance of true columnar epithelium, the flat ends resting on the subjacent elastic lamina, and the pointed extremities directed forwards.

The *membrane* of *Demours* or *Descemet* (posterior elastic lamina, Bowman), not very closely united with the fibrous part of the cornea, is transparent and glassy in appearance, firm and structureless, but very brittle and elastic; and

* Lectures on the parts concerned in the operations on the eye, and on the structure of the retina. London, 1849.

when shreds are removed they curl up always with the attached surface innermost. Its transparency is not impaired by acids, by boiling in water, or by maceration in alkalies. In thickness it varies between $\frac{1}{3000}$th and $\frac{1}{2000}$th of an inch. At its circumference the membrane breaks up into bundles of fine threads, which are partly continued into the front of the iris, forming the "pillars of the iris," and partly into the fore part of the choroid and sclerotic coats. It is lined with an epithelial covering, which resembles that on serous membranes, consisting of a single layer of flat polygonal transparent cells with distinct nuclei.

Blood-vessels and nerves.—In a state of health the cornea is not provided with blood-vessels, except at the circumference, where they form very fine capillary loops and accompany the nerves. The existence of *lymphatics* has not been satisfactorily ascertained. The *nerves* of the cornea are very numerous, according to Schlemm.* Derived from the ciliary nerves they enter the fore part of the sclerotic, and are from twenty-four to thirty-six in number. Continued into the fibrous part of the cornea, they retain their dark outline for $\frac{1}{20}$th to $\frac{1}{10}$th of an inch, and then becoming transparent, ramify and form a network through the laminated structure.

MIDDLE TUNIC OF THE EYEBALL.

This coat consists of two parts, one a large posterior segment—the choroid, reaching as far as the cornea, and formed chiefly of blood-vessels and pigmentary material; the other, a small anterior muscular part—the iris. Between these and connected with both is situated the white ring of the ciliary muscle.

Fig 462.

Fig. 462.—Choroid Membrane and Iris exposed by the removal of the Sclerotic and Cornea (after Zinn). $\frac{2}{1}$

a, one of the segments of the sclerotic thrown back; *b*, ciliary muscle and ligament; *c*, iris; *e*, one of the ciliary nerves; *f*, one of the vasa vorticosa or choroidal veins.

THE CHOROID COAT.

The choroid coat of the eye (tunica choroidea s. vasculosa) is a dark brown membrane lying between the sclerotic and the retina. It reaches forwards to the ciliary ligament, or nearly to the cornea, where it ends by a series of plaits or folds named ciliary processes, disposed in a circle projecting inwards at the back of the circumferential portion of the iris. At the hinder part, where the tunic is thickest, the optic nerve is transmitted through a circular opening. The outer surface is rough, and is connected to the sclerotic by loose connective tissue (lamina fusca of

* Berl. Encycl. Wört. art. Augapfel, Vol. iv. p. 22.

authors), and by vessels and nerves. The inner surface, which is smooth, is lined by a continuous layer of pigmentary cells.

The *ciliary processes*, about eighty-five in number, are arranged radiately in a circle. They consist of larger and smaller folds, without regular alternation, and the small folds number about one-third of the large. Each of the larger folds, measuring about $\frac{1}{10}$th of an inch in length and $\frac{1}{40}$th in depth, forms a rounded projection at its inner end, which is free from the pigment which invests the rest of the structure ; but externally they become gradually narrower, and disappear in the choroid coat : the smaller processes are only half as deep as the others. At and near their internal or anterior extremities the processes are connected by lateral loop-like projections, and are separated from the iris by pigment. The plications of the ciliary processes fit into corresponding plications of the suspensory ligament of the lens.

Fig. 463.

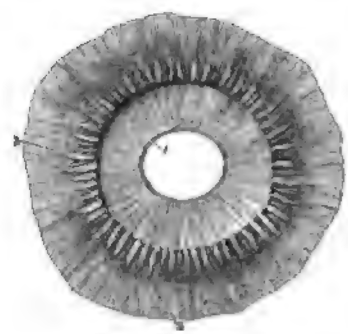


Fig. 463.—CILIARY PROCESSES AS SEEN FROM BEHIND. $\frac{3}{1}$

1, posterior surface of the iris, with the sphincter muscle of the pupil ; 2, anterior part of the choroid coat ; 3, one of the ciliary processes, of which about seventy are represented.

STRUCTURE.—From a difference in the fineness of its constituent blood-vessels, the choroidal coat resolves itself into two strata, inner and outer ;— the latter containing the larger branches, and the former the capillary ramifications.

In the *outer part* of the coat are situated the branches of the vessels. The arteries are large, and are directed forwards before they bend downwards to end on the inner surface ; whilst the veins (vasa vorticosa) are disposed in curves as they converge to four of five principal trunks issuing from the eyeball. In the intervals between those vessels are lodged elongated and star-shaped pigment cells with very fine offsets, which intercommunicate and form a network or stroma. Towards the inner part of the tunic, this network passes gradually into a web without pigment : it resembles elastic tissue in its chemical and physical properties.

The *inner part* of the choroid coat (tunica Ruyschiana s. chorio-capillaris) is formed by the capillaries of the choroidal vessels. From the ends of the large arteries the capillaries radiate in a star-like manner, and form meshes which are more delicate and smaller than in any other texture, and are finer at the back than the front of the ball. This fine network reaches as far forwards as about $\frac{1}{4}$th of an inch from the cornea, or opposite to the ending of the expansion of the optic nerve, where its meshes become larger, and join those of the ciliary processes.

On the inner surface of the tunica Ruyschiana may be detected, according to various authors, a structureless transparent membrane, the *membrane of Bruch*, underlying the pigmentary layer.

The *ciliary processes* have the same structure as the choroid, of which they are a part ; but the capillary plexus of the vessels, less fine, has meshes

with chiefly a longitudinal direction; and the ramified cells, fewer in number, are devoid of pigment towards the free extremities of the folds.

The *pigmentary layer* (choroidal epithelium, membrane of the black pigment) forms a thin dark lining to the whole inner surface of the choroid and the iris. As far forwards as the ciliary processes it consists of only a single layer of flat six-sided cells, applied edge to edge like mosaic work. Each cell contains a nucleus and more or less dense molecular contents, accumulated in greatest abundance towards the circumference of the cell, and partly obscuring the nucleus. On the ciliary processes and the iris the pigment is several layers deep, and the cells, smaller and rounded, are so filled with dark pigment as to cover up the nucleus. In the eye of the albino pigment is absent both from the hexagonal cells and the ramified corpuscles of the choroidal tunic.

Fig. 464.

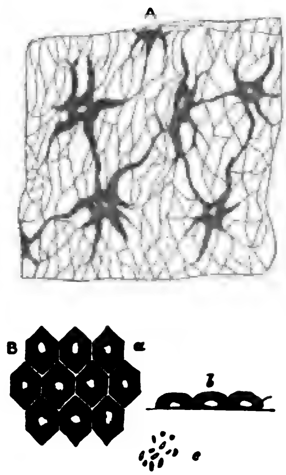


Fig. 464.—Pigment Cells of the Middle Coat (after Kölliker).

A, small portion of the choroid with the stillate or ramified cells which form its stroma. B, pigment cells, which cover the inner surface of the choroid; *a*, these cells seen from the surface, of hexagonal form, and showing nuclei in their interior; *b*, three of the same cells viewed edgeways; *c*, molecular pigment, which fills the cells.

It may be mentioned that in fishes, and in many mammals, including the ox and the sheep, the eyes of which are often selected for dissection, the choroid, instead of being uniformly lined with dark pigment, presents on a greater or less extent of its back part a silvery layer named *tapetum*. The tapetum in ruminants consists of tendinous fibres, and in carnivora and fishes of cells, filled, in the carnivora, with granular matter (Leidig), in fishes with slender rods. On its inner surface is the tunic of Ruysch, as well as the layer of hexagonal cells, which, however, is here destitute of pigment.

THE IRIS.

The iris is the contractile and coloured membrane which is seen behind the transparent cornea, and gives the tint to the eye. In its centre it is perforated by an aperture—the pupil.

By its circumferential border, which is nearly circular, the iris is connected with the choroid, the cornea, and the ciliary ligament and muscles: the free inner edge is the boundary of the pupil, and is constantly altering its dimensions during life. The iris measures $\frac{1}{2}$ an inch across, and, in a state of rest, from the circumference to the pupil about $\frac{1}{6}$th of an inch. Its surfaces look forwards and backwards. The anterior, variously coloured in different eyes, is marked by waving lines converging towards the pupil, near which they join in a series of irregular elevations; and, internal to these, other finer lines pass to the pupil. The posterior surface is covered with dark pigment; and this being removed, there is seen at the margin of the pupil a narrow circular band of fibres (sphincter muscle of the pupil), with which lines radiating inwards are blended.

The *pupil* is nearly circular in form, and is placed a little to the inner side of the centre of the iris. It varies in size according to the contraction or relaxation of the muscular fibres, and this variation ranges from $\frac{1}{20}$th to $\frac{1}{3}$rd of an inch. The movements of the iris regulate the quantity of light admitted to the eyeball, and are associated with convergence of the optic axes, and with the focal adjustment of the eye.

Structure.—Fibrous and muscular tissues form the framework of the iris, and pigment is scattered through the texture. In front and behind is placed a distinct layer of pigment cells. It is still matter of discussion whether or not in the adult a delicate epithelium is continued from the margin of the cornea over the front of the iris : it is admitted to exist in childhood.

The *fibrous* stroma consists of fibres of connective tissue directed radiatingly towards the pupil, and circularly at the circumference ; these, interweaving with one another, form a net-like web which is less open towards the surfaces.

The *muscular fibre* is of the non-striated kind, and is disposed as a ring (sphincter) around the pupil, and as rays (dilatator) from the centre to the circumference.

Fig. 465.

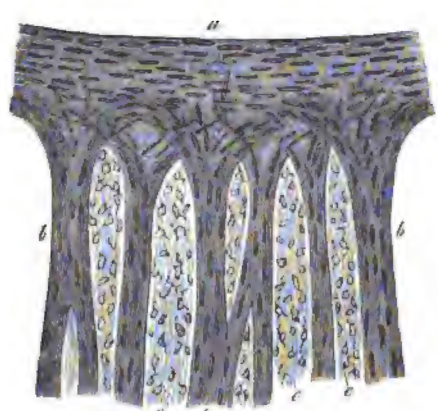


Fig. 465.—A small part of the Iris, showing the Muscular Structure (from Kölliker). $\frac{350}{1}$

The specimen is from the albino-rabbit, and has been treated with acetic acid : *a*, the sphincter muscle at the margin of the pupil ; *b*, fasciculi of the dilatator muscle ; *c*, connective tissue with nuclear cells rendered clear by the acid.

The *sphincter* is the flat narrow band on the posterior surface of the iris, close to the pupil, and is about $\frac{1}{40}$th of an inch wide. At the edge of the pupil the fibres are close together, but at the peripheral border they are separated, and form less complete rings.

The *dilatator*, less apparent than the sphincter, begins at the ciliary or outer margin of the iris, and its fibres, collected into bundles, are directed inwards between the vessels and nerves, converging towards the pupil, and forming a net-work by their intercommunications. At the pupil they blend with the sphincter, some reaching near to its inner margin.

Pigmentary elements.—In the substance of the iris anteriorly and throughout its thickness are variously-shaped and ramified pigment cells like those in the choroid membrane. The pigment contained in them is yellow, or of lighter or darker shades of brown, according to the colour of the eye. On the fore part of the iris is a thin stratum of rather oval or rounded cells with granular ramified offsets (an epithelial layer—Kölliker). At the posterior surface is a covering of dark pigment—the *uvea* of authors ; this is con-

tinuous with the pigmentary layer lining the choroid and the ciliary processes, and consists of several strata of small roundish cells filled with dark pigment. The colour of the iris depends on the pigment; in the different shades of blue eye it arises from the black pigment of the posterior surface appearing more or less through the texture, which is only slightly coloured or is colourless; and in the black, brown, and grey eye, the colour is due to the pigment scattered through the iris substance.

Fig. 466.

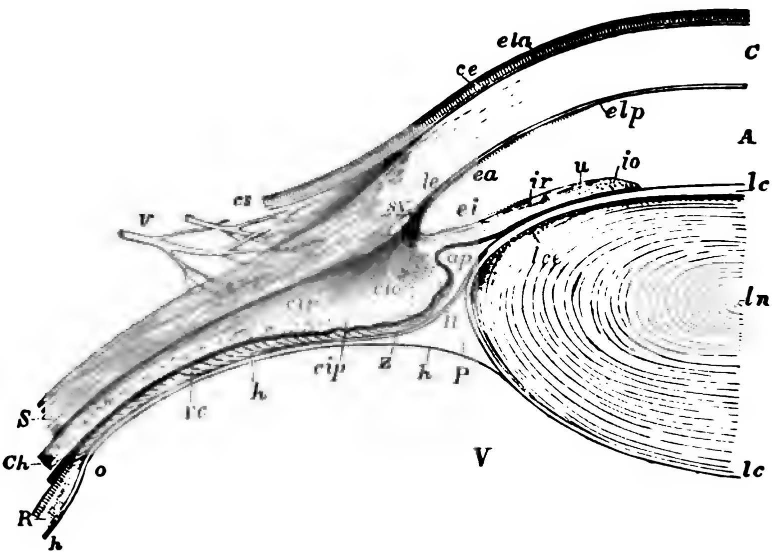


Fig. 466.—Sectional view of the Connections of the Cornea, Sclerotic, Iris, Ciliary Muscle, Ciliary Processes, Hyaloid Membrane and Lens. $\frac{?}{1}$

The specimen extends from the middle of the lens to the ora serrata on the inner side of the right eye. C, the laminated cornea; *cc*, conjunctiva corneæ; *cs*, conjunctiva scleroticæ; *ce*, epithelium of the conjunctiva; *ela*, anterior elastic layer of the cornea passing outwards in part into the conjunctiva; *elp*, posterior elastic layer; *le*, ligamentum pectinatum iridis, elastic ligament, spreading into the base of the iris, the sclerotic, and the attachment of the radiated ciliary muscle; S, the sclerotic at its thinnest part; A, the anterior aqueous chamber; *ap*, the recess forming the posterior division of the aqueous chamber; *sv*, placed at the junction of the cornea and sclerotic, points to the circular venous sinus or canal of Schlemm; *ea*, epithelium behind the cornea indicated by a dotted line; *ei*, epithelium in front of the iris similarly indicated; *ir*, radiating muscle of the iris; *io*, divided fibres of the orbicular muscle; *u*, pigment layer or uvea; *ln*, centre of the crystalline lens; *lc*, capsule of the lens; *lcc*, layer of cells in front of the lens; *cir*, radiating ciliary muscle or tensor choroideæ; *cio*, divided orbicular fibres; *cip*, ciliary process, along the inner border of which a layer of pigment is continued from the choroid to the uvea, excepting at the end of the process; *Ch*, choroid membrane; R, the retina close to the ora serrata; *rc*, the ciliary part of the retina, the structure of which is imperfectly represented; V, the vitreous humour; *h*, the hyaloid membrane; P, canal of Petit; *h'*, the hyaloid membrane continued behind the canal to the capsule of the lens; Z, zonule of Zinn, and *ll*, suspensory ligament of the lens proceeding from the hyaloid covering the ciliary process to the front of the capsule of the lens.

The *vessels* and *nerves* have a radiating arrangement through the stroma; the former giving rise to rings, one at the circumference, the other near the pupil; and the latter forming a network. See the description of the vessels and nerves of the vascular coat.

Pupillary membrane (membrana pupillaris).—In fœtal life a delicate transparent membrane thus named closes the pupil, and completes the curtain of the iris. The pupillary membrane contains minute vessels, continuous with those of the iris and of the capsule of the crystalline lens; they are arranged in loops, which converge towards each other, but do not quite meet at the centre of the pupil. At about the seventh or eighth month of fœtal life these vessels gradually disappear; and, in proportion as the vascularity diminishes, the membrane itself is absorbed from near the centre towards the circumference. At the period of birth, often a few shreds, sometimes a larger portion, and occasionally the whole membrane is found persistent. (See also the account of the development of the eye.)

CILIARY MUSCLE, LIGAMENTUM PECTINATUM AND CIRCULAR SINUS.

When the outer coat of the eyeball is separated from the choroid, a circular groove is seen passing round on the inner surface of the sclerotic, at its corneal margin. This groove is the outer wall of a venous canal, the *sinus circularis iridis* or *canal of Schlemm*. On the middle coat a corresponding groove, which completes the canal, is seen,—and this is bounded in front by a torn membranous edge bounding the anterior surface of the iris, the ligamentum pectinatum, while the thickest part of the white ring of the ciliary muscle is behind it. This canal communicates with other venous spaces which give an erectile appearance to the tissue at the base of the ciliary processes.

The *ligamentum pectinatum* consists of slight festoon-like processes of the fibres of the iris, lying in a transparent elastic fibrous tissue continuous with the posterior elastic layer of the cornea. It is a more developed structure in the eyes of the sheep and ox than in the human eye, and in them the festooned processes are prominent, giving a milled appearance like that of the edge of a coin.

The *ciliary muscle* (Bowman) forms a ring of unstriped muscular tissue about $\frac{1}{10}$th of an inch broad on the fore part of the choroid. Its fibres, yellowish-white in colour, and longitudinal in direction, are attached in front to the inner surface of the sclerotic coat; and are also connected with the terminal fibres of the posterior elastic layer of the cornea. From that origin the fibres are directed inwards and backwards in a manner which in a section appears radiated, and end by joining the choroid coat opposite and beyond the ciliary processes. The muscle is soft, and ramified pigment cells are scattered through its substance.

Concealed by the longitudinal or radiated fibres is a ring of fibres taking a circular direction, and which were still described as the ciliary ligament after the radiated fibres had been admitted to be muscular. This set constitutes the circular muscle of H. Müller.

The ciliary muscle appears to be in some way effective in producing the change in the form of the lens which takes place in accommodation of the eye to near vision (see Allen Thomson in "Glasgow Medical Journal" for 1859).

VESSELS AND NERVES OF THE MIDDLE TUNIC OF THE EYE.

The *arteries of the choroid* and the *ciliary processes* are derived from the posterior and anterior ciliary vessels. The posterior consist of two sets, distinguished as the short and the long. The *short* (posterior) *ciliary branches* of the

ophthalmic artery pierce the sclerotic close to the optic nerve, and divide into branches which pass forward in meridional directions in the choroid membrane. Communicating freely they diminish in size, and entering the choroid form a close net-work of fine capillaries (*tunica Ruyschiana*) already described.

Fig. 467.

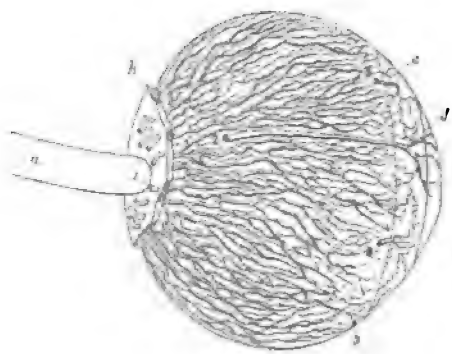


Fig. 467.—Lateral View of the Arteries of the Choroid and Iris (from Arnold). ⅔

a, optic nerve; *b*, part of the sclerotic left behind, the greater part and the cornea having been removed anteriorly; *c*, ciliary muscle; *d*, iris; 1, posterior ciliary arteries piercing the sclerotic and passing along the choroid; 2, one of the long posterior ciliary arteries; 3, several of the short or anterior ciliary arteries.

The *veins of the choroid coat* constitute an outer layer, partially separable from the arterial net-work, and easily recognised by the direction of the larger vessels. These converge to four nearly equidistant trunks, which pass through the sclerotic about half way between the margin of the cornea and the entrance of the optic nerve, and pour their contents into the ophthalmic vein. From their whorl-like arrangement they are known as the *vasa vorticosa*.

Fig. 468.

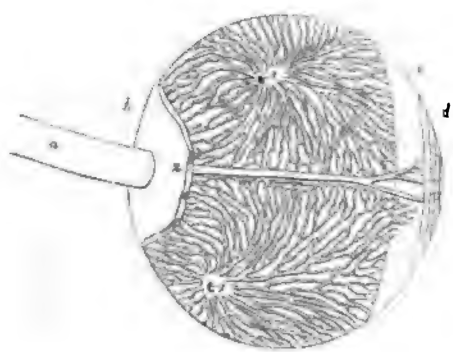


Fig. 468.—Lateral View of the Veins of the Choroid (from Arnold).

The preparation is similar to that represented in the previous figure. 1, 1, two trunks of the venæ vorticosæ at the place where they leave the choroid and pierce the sclerotic coat.

The *blood-vessels of the ciliary processes* are very numerous, and are derived from the anterior ciliary, and from those of the fore part of the choroidal membrane. Several small arterial branches enter the outer part of each ciliary process, at first running parallel to each other and communicating sparingly. As they enter the prominent folded portion, the vessels become tortuous, subdivide minutely, and inosculate frequently by cross branches. Finally they form short arches or loops, and turn backwards to pour their contents into the radicles of the veins.

On the free border of the fold, one artery, larger than the rest, extends

the whole length of each ciliary process, and communicates through intervening vessels with a long venous trunk which runs a similar course on the attached surface.

Fig. 469.

Fig. 469.—Injected Vasa Vorticosa of the Choroid Coat (from Sappey). $\frac{20}{1}$

1, one of the larger veins; 2, small communicating vessels; 3, branches dividing into the smallest vorticose vessels.

Arteries of the iris.—The special arteries of the iris are the long ciliary and the anterior ciliary.

The *long* (posterior) *ciliary arteries*, two in number, and derived from the ophthalmic, pierce the sclerotic a little before, and one on each side of the optic nerve. Having gained the interval between the sclerotic and choroid coats, they extend horizontally forwards through the loose connective tissue (*membrana fusca*) to the ciliary muscle. In this course they lie nearly in the horizontal plane of the axis of the eye-ball, the outer vessel being however a little above, and the inner one a little below the level of that line. A short space behind the fixed margin of the iris each vessel divides into an upper and a lower branch, and these anastomosing with the corresponding vessels of the opposite side and with the anterior ciliary, form a vascular ring (*circulus major*) in the ciliary muscle. From this circle smaller branches arise to supply the muscle; whilst others converge towards the pupil, and there, freely communicating by transverse offsets from one to another, form a second circle of anastomosis (*circulus minor*), and end in small veins.

The *anterior ciliary arteries*, five or six in number, but smaller than the vessels just described, are supplied from the muscular and lachrymal branches of the ophthalmic artery, and pierce the sclerotic about a line behind the margin of the cornea; finally, they divide into branches which supply the ciliary processes, and join the circulus major.

Besides these special arteries, numerous minute vessels enter the iris from the ciliary processes.

The *veins of the iris* follow closely the arrangement of the arteries just described. The circular sinus communicates with this system of vessels.

The *nerves* for the supply of the iris are named ciliary: they are numerous and large; and, before entering the iris, divide in the substance of the ciliary muscle.

Fig. 470.

Fig. 471.

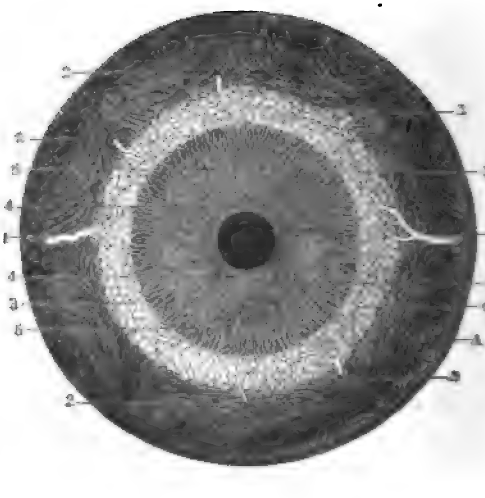


Fig. 470.—Vessels of the Choroid, Ciliary Processes and Iris of a Child (from Kölliker after Arnold). $\frac{10}{1}$

a, capillary network of the posterior segment of the choroid ending at *b*, the ora serrata; *c*, arteries of the corona ciliaris, supplying the ciliary processes *d*, and passing into the iris *e*; *f*, the capillary network close to the pupillary margin of the iris.

Fig. 471.—Front View of the Bloodvessels of the Choroid Coat and Iris from before (from Arnold). $\frac{21}{1}$

A, anterior part of the choroid; B, iris; C, ciliary muscle, &c.; 1, 1, long posterior ciliary arteries; 2, five of the anterior ciliary arteries ramifying towards the outer margin of the iris; 3, loop of communication between one of the anterior and one of the long posterior ciliary arteries; 4, internal circle and network of the vessels of the iris; 5, external radial network of vessels.

Fig. 472.

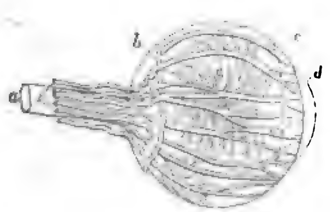


Fig. 472.—Lateral View of the Ciliary Nerves (from Arnold).

a, optic nerve; *b*, back part of the sclerotic; *c*, ciliary muscle, &c.; *d*, iris; *e*, outer surface of the choroid coat; 1, five of the ciliary nerves passing along the sheath of the optic nerve, piercing the sclerotic posteriorly, and thence passing forward on the choroid membrane to the ciliary muscle and iris. The nerves are represented too large.

The *ciliary nerves*, about fifteen in number, and derived from the lenticular ganglion and the nasal branch of the ophthalmic division of the fifth nerve, pierce the sclerotic near the entrance of the optic nerve, and come immediately in contact with

the choroid. They are somewhat flattened in form, are partly embedded in grooves on the inner surface of the sclerotic, and communicate occasionally with each other before supplying the cornea and entering the ciliary muscle. When the sclerotic is

Fig. 473.

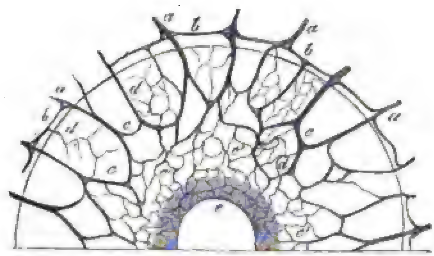


Fig. 473.—DISTRIBUTION OF NERVES IN THE IRIS (from Kölliker). $\frac{50}{1}$

The preparation was taken from the eye of an albino rabbit, and was treated with soda. *a*, smaller branches of the ciliary nerves advancing from the choroid; *b*, loops of union between them at the margin of the iris; *c*, arches of union in the iris; *c'*, finer network in the inner part; *d*, some of the terminations of single nerve filaments in the outer part of the iris; *e*, sphincter pupillæ muscle.

carefully stripped from the subjacent structures, these nerves are seen lying on the surface of the choroid. Within the ciliary muscle the nerves subdivide minutely, a few being lost in its substance, but the greater number pass on to the iris. In the iris the nerves follow the course of the blood-vessels, dividing into branches, which communicate with one another as far as the pupil. In the iris they soon lose their dark outline, and their mode of termination is not ascertained.

RETINA OR NERVOUS TUNIC.

The retina is a delicate almost pulpy membrane, which contains the terminal part of the optic nerve. It lies within the choroid coat, and rests on the hyaloid membrane of the vitreous humour. It extends forwards nearly to the outer edge of the ciliary processes of the choroid, where it ends in a finely indented border—*ora serrata*. From this border there is continued

Fig. 474.

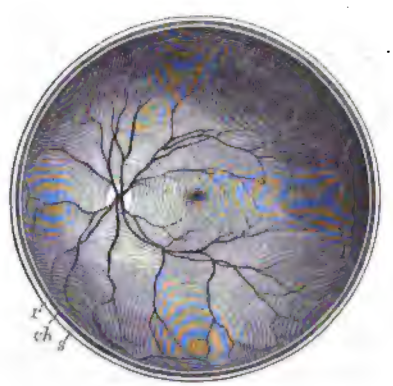


Fig. 474.—THE POSTERIOR HALF OF THE RETINA OF THE LEFT EYE VIEWED FROM BEFORE (after Henle). $\frac{3}{1}$

s, the cut edge of the sclerotic coat; *ch*, the choroid; *r*, the retina: in the interior at the middle the macula lutea with the depression of the fovea centralis is represented by a slight oval shade; towards the left side the light spot indicates the colliculus or eminence at the entrance of the optic nerve, from the centre of which the arteria centralis is seen spreading its branches into the retina, leaving the part occupied by the macula comparatively free.

onwards a thin layer of transparent nucleated cells (not nerve elements) of an elongated or cylindrical form, constituting the pars ciliaris retinæ, which reaches as far as the tips of the ciliary processes, and there gradually disappears. The thickness of the retina diminishes from behind forwards. In the fresh eye it is translucent and of a light pink colour; but after death it soon becomes opaque, and this change is most marked under the action of

water, alcohol, and other fluids. The outer surface is rough or slightly flocculent when the choroid is detached, and is in contact with the pigmentary layer; and from it a more or less complete stratum may be raised with care in a perfectly fresh eye. This layer, at first called membrane of Jacob from its discoverer, is now generally recognised as the columnar layer. The inner surface of the retina is smooth, and is merely applied to the vitreous body within it: on it the following objects may be seen. In the axis of the ball is a *yellow spot*—macula lutea (limbus luteus, Sömmerring), which is somewhat elliptical in shape, and about $\frac{1}{20}$th of an inch in diameter: in its centre is a slight hollow, *fovea centralis*, and as the retina is thinner here

Fig. 475.

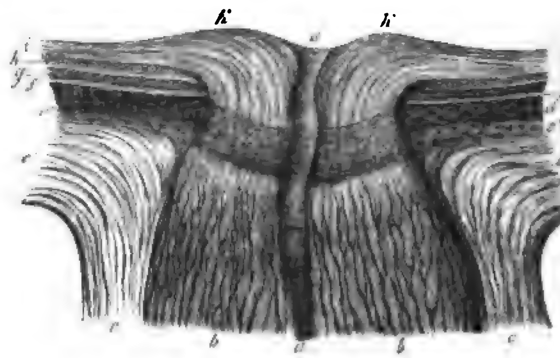


Fig. 475.—Section through the Middle of the Optic Nerve and the Tunics of the Eye at the Place of its Passage through them (from Kölliker after Ecker).

The drawing was taken from a chromic acid preparation: *a*, arteria centralis retinæ; *b*, fasciculi of optic nerve fibres with neurilemma; *c*, sheath of the optic nerve, passing into *c'*, the sclerotic coat; *c''*, outermost pigmental layer of the choroid or membrana fusca; *d*, choroid and inner pigment layer; *e*, *f*, columnar layer of the retina; *g*, the two granular layers; *h*, layer of nerve-cells; *i*, layer of nerve-fibres; *k*, colliculus or eminence at the entrance of the optic nerve; *l*, lamina cribrosa.

than elsewhere, the pigmentary layer of the choroid is visible through it, giving rise to the appearance of a hole through the tunic. About $\frac{1}{10}$th of an inch inside the yellow spot is the round disc, *porus opticus*, where the optic nerve expands, and in its centre the point from which the vessels of the retina branch. At this place the nervous substance is slightly elevated so as to form an eminence (colliculus nervi optici).

Structure.—The retina, when examined microscopically in vertical sections, exhibits a series of dissimilar strata, together with structures not confined to one stratum. (1st) Externally is the columnar layer; (2nd), in the middle is the granular layer, comprising the external nuclear, the internuclear, the internal nuclear, and the molecular layers; and (3rd) internally is the nervous layer, consisting of three strata, one of nerve cells, another of nerve fibres—the ramifications of the optic nerve, and on the inner surface of this last, a limiting membrane. (4th) Traversing the strata from the columnar layer to the limiting membrane, are placed vertical fibrils of varying kinds at different depths, and not fully ascertained to be continuous,—the radiating fibres of Müller. (5th) Blood-vessels distributed in the retina, are placed chiefly towards the inner surface.

1. The *columnar layer* (stratum bacillorum), consists of innumerable thin *rods*, placed vertically side by side like palisades, and of other larger bodies, more or less thickly interspersed among these, and named *cones*. These

Fig. 476.

Fig. 476.—Vertical Section of a Small Part of the Retina (after Kölliker). $\frac{350}{1}$

A, entire section of a small part of the retina; B, two cones represented separately in their connection with the fibres of Müller and other structures; C, two rods represented separately in their connection with the granules, fibres of Müller, and the nerve-cells; 1, columnar layer; *a*, in A and C, the rods, in B, the terminal part of the cone; *b*, cones; 2, granular layer; *c*, outer layer of nuclei (striated corpuscles of Henle); *d*, inner layer of nuclei; *f*, inter-nuclear layer; 3, nervous layer; *g*, fine molecular substance outside *h*, the nerve cells; *k*, nerve fibres; *l*, membrana limitans; *e*, inner ends of the fibres of Müller resting on the limiting membrane.

structures are glistening, soft, easily destroyed, and lose their characters quickly in fluids. The rods are of uniform diameter, and are abruptly truncated externally. The cones are flask-shaped in the inner part of their extent, and taper to a rod-like extremity externally. Each cone rests on a pyriform cell continuous with it, and forming the extremity of a fibre of Müller; while the rods end internally in pointed extremities ranging with these pyriform cells, and represented as formed by similar bodies (Kölliker); but this continuity with Müllerian fibres is still disputed. The dilated portions of the cones present granular contents, and a similar appearance is described in the inner halves of the rods. At the outer ends the rods project somewhat farther than the cones. When the outer surface of the retina is viewed about midway between its centre and margin with a strong enough magnifying power, a number of minute globular-looking bodies, the ends of the rods appear; and between them, at a deeper level, other

Fig. 477.

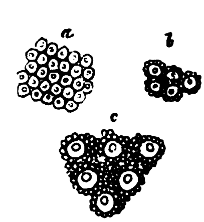


Fig. 477.—Outer Surface of the Columnar Layer of the Retina (from Kölliker). $\frac{350}{1}$

a, part of the columnar layer within the macula lutea, where only cones are present; *b*, part near the macula, where a single row of rods intervenes between the cones; *c*, from a part of the retina midway between the macula and the ora serrata, showing a preponderance of the rods.

transparent larger bodies, the swellings of the cones, are seen, with a smaller circle within each—the end of its narrower part. Towards the margin the rods become more numerous; near the centre the cones predominate; and in the macula lutea the cones alone are seen.

2. The *external and internal nuclear* divisions of the *granular layer* are two collections of rounded and oval corpuscles, refracting light pretty strongly. The corpuscles of the internal nuclear layer are small cells with large nuclei,

as are also some, at least, of those of the outer layer, namely, the pyriform bodies supporting the cones. But, according to recent investigations of Henle, whose statements have been corroborated by Ritter as holding good in the mammals generally, the bodies which constitute the bulk of the outer nuclear layer, are elliptical corpuscles, which, when perfectly fresh, exhibit transverse striation similar to muscular fibre, to the extent of three dark lines alternating with clear substance in each, but which soon break up into globules.

Fig. 478.

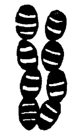


Fig. 478.—Striped Elliptical Corpuscles of the External Nuclear Layer of the Retina (from Henle). $\frac{800}{1}$

The *internuclear layer*, which lies between the layers now referred to, is a clear space of unequal depth, vertically striated, and having likewise a molecular appearance. The molecular basis is more marked in a thin stratum which intervenes between the internal nuclear layer and the nerve cells, and which, therefore, has been distinguished as the *molecular layer*.

3. *Nervous layer.*—*a.* The *cellular layer* consists of nerve cells with a fine molecular material interspersed among them. At the bottom of the eye over the yellow spot they are thickest (from 8 to 10 cells deep), and decrease in quantity in front; so that at a fifth of an inch from the ora serrata they are only scattered in clusters. Around the entrance of the optic nerve there is only a single stratum of these elements. The cells when fresh are transparent and nucleated, being roundish or pear-shaped in outline, and are furnished with from two to six ramified offsets. By their internal offsets the cells are continuous with the nerve fibres beneath; by horizontal offsets they are united one with another; and by those which pass outwards they are connected with the corpuscles of the internal nuclear layer.

b. The *nerve-fibre layer* consists of nerve fibres directed forwards from the optic nerve, and collected into small bundles, which, compressed laterally, intercommunicate and form a delicate web with narrow elongated meshes. This stratum diminishes in thickness forwards, and ends at the ora serrata: it forms a continuous membrane, except at the yellow spot, where the nerve fibres are wanting. According to Bowman, the fibres, which lose their dark outline on reaching the retina, consist there of an axis-cylinder only. It is now well established that they terminate in the nerve cells on which they lie, and this is the only mode of their termination which has been fully ascertained.

c. Membrana limitans and connective tissue.—The limiting membrane lines the inner surface of the retina, separating it from the vitreous body. It is an extremely thin and delicate membrane, which can be detached in shreds; and it agrees with the other glassy membranes of the eye-ball in not being affected by alkalies, maceration, or boiling. On its retinal surface it is studded with the broadened insertions of vertical threads of connective tissue, which separate the nerve fibres into bundles, and form the inner parts of the Müllerian fibres. Nuclei apparently exist both in these and in the membrana limitans itself. Delicate homogeneous connective tissue, likewise, enters into the composition of the layers of the retina as far outwards as the bases of the rods and cones, and gives there the appearance of a horizontal line, the external limitary membrane of Schultze.

4. *Radiating fibres of Müller, and connections of the different elements of the retina.*—From the foregoing description it will be gathered that the history of

the Müllerian fibres is still incomplete. Indeed, the minuteness and delicacy of their structure renders their investigation one of the most difficult subjects of anatomical inquiry. Heinrich Müller, to whom science chiefly owes the advance which has of late years been made towards the elucidation of the minute structure of the retina, described radiating fibres extending vertically from the rods and cones to the membrana limitans, interrupted in their course by the corpuscles of the outer and inner nuclear layers, and connected with the nerve cells. He subsequently recognised the vertical fibres in the internal layers as connective tissue,—a view now universally adopted. It appears to be clearly established, that from the pyriform corpuscle at the base of each cone a thread passes inwards to a corpuscle of the internal nuclear layer. It is also stated that more slender threads unite the rods with the deep layers; and Kölliker represents a thread passing out from a corpuscle of the internal nuclear layer as afterwards dividing into branches, on which are placed corpuscles of the external nuclear layer, and which terminate in rods. This account of the structure seems best to accord with the physiological view now very generally held, that the columnar layer is the more immediate seat of the formation of a distinct image in vision, and of the reception of visual impressions from rays of light impinging upon the retina. It is right to state, however, that a different view is taken by Henle, who believes that the rods are free, and that the fibres observed by H. Müller and Kölliker are artificial products, the result of coagulation by re-agents. Henle regards the retina as composed of an outer part, which he terms the mosaic layer, and which comprises the columnar structures of Jacob's membrane, and the external nuclear layer, and is destitute of blood-vessels; and an inner nervous part comparable to the structure found in the cerebral convolutions, and consisting of a stratum of nerve fibres and of two strata of nerve cells alternating with granular strata; the corpuscles of the internal nuclear layer being considered by him as nerve cells of a smaller order than those of the cellular layer.

5. *Vessels of the retina.*—An artery enters and a vein leaves the retina between the bundles of fibres of the optic nerve.

The artery (arteria centralis retinæ) is an offset of the ophthalmic, and divides into four or five primary branches as soon as it enters the eye-ball. These larger offsets are situated at first on the inner surface of the nerve fibres, but they soon pass between these into the stratum of nerve-cells, where they form a network of very fine capillaries with rather wide meshes, which reaches in front to the ora serrata.

The vein corresponding to this artery has a similar distribution: it terminates in the ophthalmic vein. In animals there is a circular vessel (circulus venosus retinæ) following the line of the ora serrata.

Constituents of the retina in the yellow spot.—In this part of the retina the several layers above described undergo some modification: the following are the alterations in the strata from without inwards, viz.:—In the columnar layer, only the cones are present, but they are set close together and are smaller than elsewhere. The granular layer is absent opposite the fovea centralis. The nervous layer is thus modified: the nerve cells cover the whole spot, like laminated epithelium, and rest internally on the membrana limitans; but the molecular substance outside them is absent over the fovea centralis; the nerve fibres extend only into the circumference of the spot amongst the cells, without forming a layer over it. The fibres of Müller are found at the circumference but not over the fovea centralis; they have an oblique, almost horizontal direction, and present a specially nerve-

like appearance. Only capillary vessels occupy the yellow spot, the larger branches passing round it.

Fig. 479.

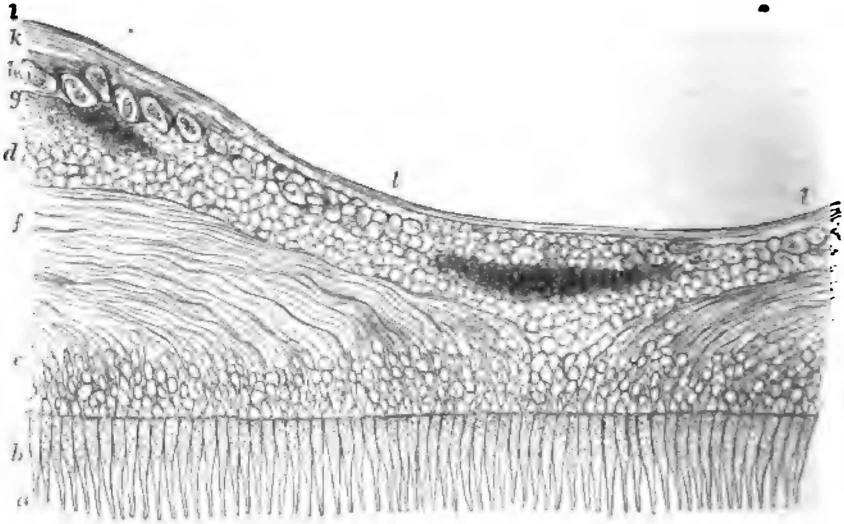


Fig. 479.—VERTICAL SECTION OF THE RETINA THROUGH THE MIDDLE OF THE FOVEA CENTRALIS (from Henle.) $\frac{300}{1}$

This figure is taken from a preparation of the human retina hardened in alcohol, and is designed to show the peculiarities of this part as compared with other regions of the retina, viz., the obliquity of the Müllerian fibres, the thinness of the layer of nerve fibres, and the absence of the granular layer in the centre. *a*, *b*, cones of the columnar layer; *c*, external nuclear layer; *d*, internal nuclear layer; *f*, external fibrous layer; *g*, molecular substance next to *h*, the ganglionic layer; *k*, the layer of nerve fibres; *l*, the internal limiting membrane.

The *yellow colour* of the macula lutea is deepest towards the centre, and is due to a pigment which imbues all the layers except the columnar: it does not appear to be contained in cells, and is soon removed after death by the action of water.

Ciliary part of the retina.—The structure which has been named the ciliary part of the retina is situated in front of the ora serrata, and extends thence over the inner ends of the ciliary processes to the base of the iris (therefore, over the whole corona ciliaris). Though entirely destitute of the nervous parts of the retinal structure, it is still in continuity with the substance of the retina, and in the form of a grey membrane, adheres to the ciliary processes and zonule of Zinn, and is usually in great part detached from the neighbouring parts along with the latter. According to Kölliker, this layer consists of elongated nucleated cells, which in the human subject are broad externally, and with flat or forked bases set upon the internal limiting membrane. He regards these cells as probably corresponding to the Müllerian fibres, and as constituting in this place the only representative of the retinal structure.

On the structure of the retina may be consulted Heinrich Müller, in Siebold und Kölliker's Zeitschrift, 1851 and 1856; M. Schultze, "Obs. de retinæ Struct. penit.," 1859; Goodsir, in Edin. Med. Journal, 1855; Kölliker, Handbuch d. Gewebelehre, 4th ed., 1863; and Henle, Handbuch d. System. Anatomie, vol. ii., 1866.

Fig. 480.

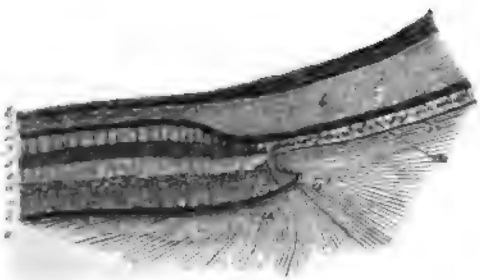


Fig. 481.

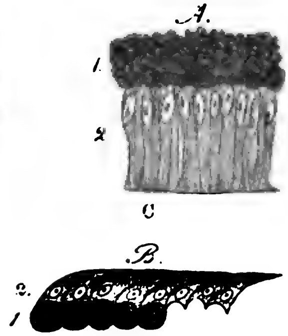


Fig. 480.—Vertical Section through the Choroid and Retina near the Ora Serrata (from Kölliker). $\frac{80}{1}$

a, hyaloid membrane; *a'*, indications of fibres which radiate from the anterior margin of the retina into the vitreous body; *b*, limiting membrane and fibrous layer of the retina; *c*, ganglionic layer with a few cells shown; *d*, inner nuclear layer; *e*, internuclear substance; *f*, outer nuclear layer; *g*, columnar layer; *h*, dark pigment; *i*, middle layer of the choroid; *l*, beginning of one of the ciliary processes; *m*, ciliary part of the retina. (The recess shown at *a'* is not constant.)

Fig. 481.—A Small Portion of the Ciliary Part of the Retina (from Kölliker). $\frac{350}{1}$

A, human; B, from the ox; 1, pigment cells; 2, cells forming the ciliary part.

THE VITREOUS BODY.

The vitreous body is the largest of the transparent parts occupying the centre of the eye-ball. Globular in form, it occupies about four-fifths of the ball, and supports the delicate retina, being in contact with the membrana limitans. On the fore part it is hollowed out for the reception of the lens and its capsule, and behind it is more closely connected with the retina than at the sides, having received at that part offsets of the retinal vessels in fœtal life. It is quite transparent, and like a thin jelly in its interior. Its surface is formed by a thin enveloping glassy membrane, named hyaloid, and as long as this membrane is entire, it retains its form in water. No vessels enter it, and its nutrition must be therefore dependent upon the surrounding vascular textures—viz., the retina, and the ciliary processes.

The *hyaloid* is an extremely thin and clear membrane. When traced forwards it is found to be connected, opposite the outer part of the ciliary processes, with a firm membrane passing in front of the marginal part of the lens (suspensory ligament), while a thinner layer, proceeding inwards from this, becomes united with the posterior layer of the capsule of the lens, so that it is doubtful whether or not the membrane is prolonged between the capsule and the vitreous body. On the inner surface of the hyaloid are a few delicate nuclei. Fibres have been supposed to be pro-

longed inwards from it, to form cells for the contained fluid, but observations with the microscope do not show any in the adult, though in the fœtus there are fibres in the interior of the vitreous mass, with "minute

Fig. 482.

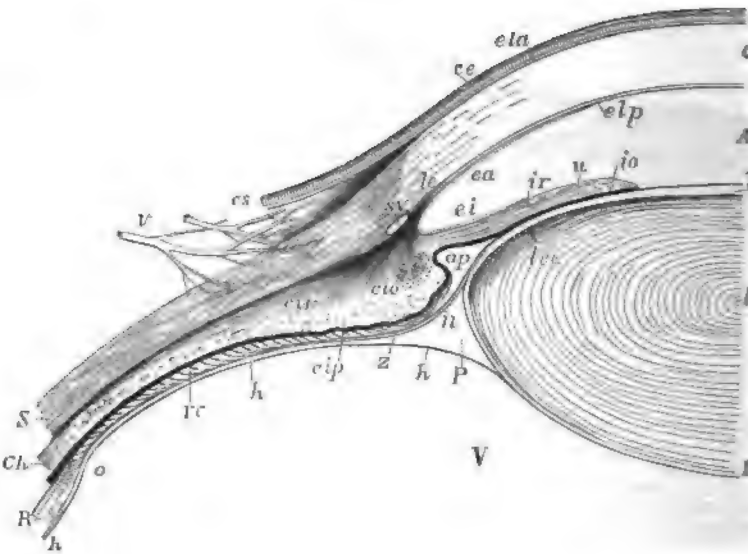


Fig. 482.—Vertical Section of a Part of the Eyeball, showing the Connections of the Cornea, Sclerotic, Iris, Ciliary Muscle, Hyaloid, and Lens. §

The full description of this figure will be found at p. 720 : the following references apply to the lens and parts connected with it. A, the anterior aqueous chamber in front of the pupil ; *ap*, the recess forming the posterior division of the aqueous chamber, the iris resting between this and the pupil on the surface of the lens ; *ir*, radiating fibres of the iris or dilatator pupillæ muscle ; *io*, orbicular fibres or sphincter muscle ; *u*, pigment layer of the iris or uvea ; *ln*, the lens at its centre ; *lc*, its capsule ; *lce*, granular or cellular layer in front of the lens : this layer is seen to terminate abruptly at the margin of the lens, where the new fibres of the lens are developed, and from whence the nuclei of the fibres extend for a certain depth inwards in an irregular plane in the growing lens ; *h*, the hyaloid membrane ; Z, the zonule of Zinn ; P, the canal of Petit ; *ll*, in front of it the suspensory ligament of the lens ; *h'*, the part of the hyaloid which closes the canal of Petit behind and extends to the posterior surface of the lens ; V, the vitreous humour.

nuclear granules" at their point of junction. (Bowman.) It is still doubtful how far the appearances of lamination produced by the action of chromic acid, or of radiated fibrillation resulting from congelation, are true indications of any actually existing structure in the interior of the vitreous humour.

The *fluid* collected from the vitreous body by puncturing it resembles water : it contains, however, some salts with a little albumen.

THE LENS AND ITS CAPSULE.

The lens, enclosed in a capsule, is situated behind the pupil, and in front of the vitreous body.

The *capsule* of the lens, a transparent glass-like membrane closely surrounding the contained body, is hard and brittle, especially in front, but very elastic and permeable to fluid. The anterior surface is in contact with the iris towards the pupil, and recedes from it slightly at the circumference; the posterior rests closely on the vitreous body. Around the circumference is a space to be afterwards noticed, the canal of Petit. The fore part of the capsule is several times thicker than the back, as far out as to $\frac{1}{18}$th of an inch from the circumference, where the suspensory ligament joins it; but beyond that spot it becomes thinner, and it is thinnest behind. In its nature the capsule of the lens resembles the glassy membrane at the back of the cornea, for it is structureless, and remains transparent under the action of acids, alcohol, and boiling water; and when ruptured, the edges roll up with the outer surface innermost. (Bowman.)

Connecting the anterior wall of the capsule closely to the lens is a single layer of granular and nucleated polygonal cells, which ends abruptly where the capsule comes in contact with the hyaloid membrane. The place of termination of this cellular layer round the margin of the lens corresponds to the line from which the fibres of the lens are developed. There is no such layer of cells on the posterior wall of the capsule, but in hardened specimens various reticulated appearances may be detected, which probably arise, as supposed by Henle, from the pressure one on another of globules of a fluid separated from the lens after death, and known as liquor Morgagni.

No vessels enter the capsule of the lense in the adult. In the fœtus it receives an artery behind, which is named the *capsular* artery. This vessel leaves the arteria centralis retinæ at the centre of the optic nerve, and passing through the substance of the corpus vitreum, enters the posterior portion of the capsule of the lens, where it divides into radiating branches. These form a fine network, turn round the margin of the lens, and extend forwards to become continuous with the vessels in the pupillary membrane and the iris.

Some authors (Albinus, Zinn, &c.) state that they have traced vessels from the capsule into the substance of the lens itself.

THE LENS.

The lens (lens crystallina) is a doubly convex transparent solid body, with a rounded circumference. Its convexity is not alike on the two surfaces, being greatest behind, and the curvature is less at the centre than towards the margin. It measures about $\frac{1}{3}$rd of an inch across, and $\frac{1}{5}$th from before backwards. In a fresh lens the outer portion is soft and easily detached; the succeeding layers are of a firmer consistence; and in the centre the substance becomes much harder, constituting the nucleus. On the anterior and posterior surfaces are faint white lines directed from the poles towards the circumference; these in the adult are somewhat variable and numerous on

Fig. 483.

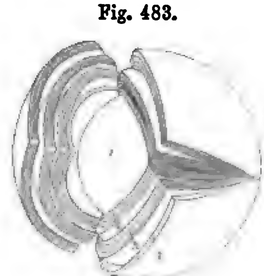


Fig. 483.—Laminated Structure of the Crystalline Lens (from Arnold). $\frac{4}{1}$

The laminæ are split up after hardening in alcohol. 1, the denser central part or nucleus; 2, the successive external layers.

the surface, but in the fœtal lens throughout, and towards the centre of the lens in the adult, they are three in number, diverging from each other like rays at equal angles of 120°. The lines at opposite poles have an intermediate position (not being over one another): they are the edges of planes or septa projecting vertically inwards to the centre of the lens, and receiving the ends of the lens fibres which are collected upon them.

Fig. 484.

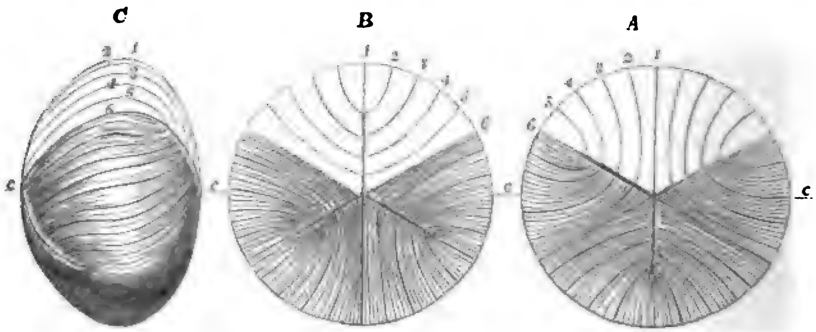


Fig. 484.—Outlines illustrating the Course of the Fibres in the Fœtal Crystalline Lens.

This diagram represents the typical or more simple state of the fibres in the full-grown fœtal or infantile condition; the three dotted lines radiating at equal angles 120° from the centre indicate the position of the intersecting planes, where they reach the surface; the figures 1, 2, 3, 4, 5, and 6, indicate certain fibres selected arbitrarily at equal distances in one-sixth part of the lens to show their course from the front to the back; A, the anterior surface; B, the posterior surface; C, the lateral aspect: in these several figures, for the sake of clearness, a few lines only are introduced into the upper third, while in the lower two-thirds a greater number are marked; but no attempt is made to represent the number existing in nature; the parts of the dotted line marked *c*, are on a level with the centre of the several lenses.

Fig. 485.

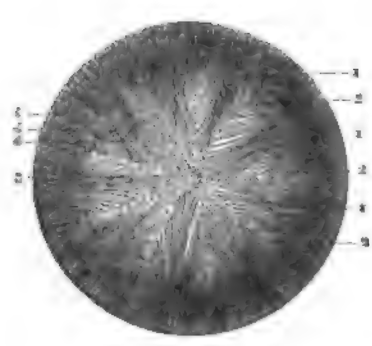


Fig. 485.—Front View of the Fibrous Structure of the Adult Lens (from Sappey after Arnold).

In this figure more numerous planes of intersection of the fibres are shown than in fig. 484.

Structure.—When the lens has been dried, or hardened by immersion in spirit, boiling water, or other fluid capable of rendering it firm and white, concentric laminæ, narrowing to a point at the poles, may be detached from it. The laminæ are further composed of microscopic fibres, which adhere together by wavy or slightly serrated margins. The lens is albuminous in its composition, and is devoid of blood-vessels; and at the planes of intersection a finely granular homogeneous material takes the place of the fibres.

The *fibres of the lens* are somewhat flattened threads, about $\frac{1}{5000}$th of an inch wide, and are directed over the edge of the lens from the planes on one surface to those on the other. In their course between the opposite surfaces, no fibre passes from pole to pole, but the fibres beginning in the pole or centre of one surface terminate in the end of a plane on the opposite surface, and vice versâ; the intervening fibres passing to their corresponding places between. Some of the superficial fibres possess transparent nuclei, at nearly regular intervals. In the more superficial fibres of the growing lens the nuclei occupy very regularly the equatorial part. At their ends, where the fibres meet the planes, they are soft and indistinct; and at the middle part, where they are placed on the margin of the lens, they are widest and best marked. The fibres are six-sided prisms, flattened in the plane of the lamina in which they lie. The edges are bevelled and sinuous; they are very regularly toothed at the edges in fishes and some other animals for more perfect junction with those in the same plane; but in man and mammals, the edge is only slightly jagged or irregularly serrated.

Fig. 486.

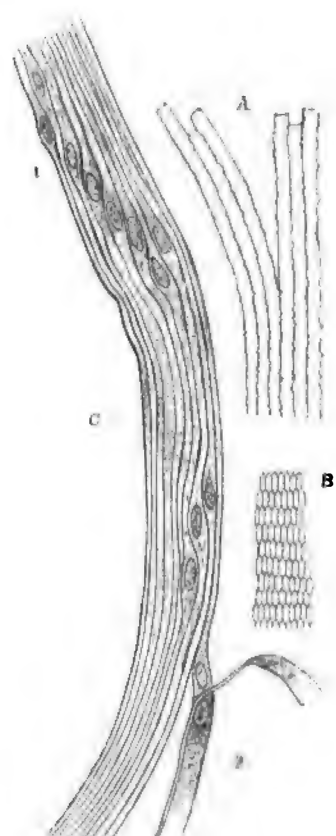


Fig. 486.—Magnified View of the Fibres of the Crystalline Lens.

A, longitudinal view of the fibres of the lens from the ox, showing the serrated edges. B, transverse section of the fibres of the lens from the human eye (from Kölliker). C, longitudinal view of a few of the fibres from the equatorial region of the human lens (from Henle). $\frac{350}{1}$ The most of the fibres are seen edgeways and towards 1, present the swellings and nuclei of the "nuclear zone;" at 2, the flattened sides of two fibres are seen.

Fig. 487.

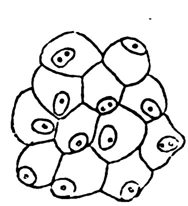


Fig. 487.—Cells connecting the Lens with its Capsule (from Bowman). $\frac{350}{1}$

Changes in the lens by age.—In the *fœtus*, the lens is nearly spherical: it has a slightly reddish colour, is not perfectly transparent, and is softer, and more readily broken down than at a more advanced age.

In the *adult*, the anterior surface of the lens becomes more obviously less convex than the posterior; and the substance of the lens is firmer, colourless, and transparent.

Fig. 488.

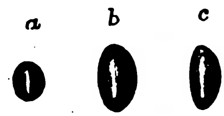


Fig. 488.—Side Views of the Lens at Different Ages.

a, at birth with the deepest convexity; *b*, in adult life with medium convexity; *c*, in old age with considerable flattening of the curvatures.

In *old age*, it is more flattened on both surfaces; it assumes a yellowish or amber tinge, and is apt to lose its transparency as it gradually increases in toughness and specific gravity.

SUSPENSORY LIGAMENT OF THE LENS AND CANAL OF PETIT.

The *suspensory ligament* of the lens—Retzius—(Zonula of Zinn) is a slender but tolerably firm transparent membrane, which, attached to the fore part of the capsule of the lens close to its circumference, passes outwards to join the hyaloid membrane of the vitreous humour at its most anterior convex part, opposite the ora serrata of the retina, and assists in retaining the lens in its place. On the anterior surface small streaks of pigment are observable after its separation from the other membranes, and when this pigment is removed by washing, small but regular folds—processus ciliares zonulæ—come into view near the lens; these are plaits in the membrane, and are received into the intervals between the ciliary processes of the choroid coat, into which they fit. Between the folds and the lens-capsule is a slight interval free from plaits, which forms part of the boundary of the posterior aqueous chamber. The posterior surface is turned towards the hyaloid membrane, from which it is separated near the lens by a space named the canal of Petit.

The suspensory ligament has chemical properties similar to those of the capsule of the lens, but in it parallel or slightly radiating longitudinal fibres may be recognised, which are stiff, elastic, and pale, resembling those of elastic tissue, being less pliable and less acted on by acetic acid than those of connective tissue.

Fig. 489.

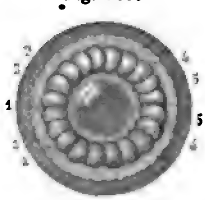


Fig. 489.—View from before of the Canal of Petit inflated (from Sappey).

The anterior parts of the sclerotic, choroid, iris and cornea having been removed, the remaining parts are viewed from before, and the canal of Petit has been inflated with air through an artificial opening. 1, front of the lens; 2, vitreous body; 3, outer border of the canal of Petit; 4, outer part of the Zonule of Zinn; 5, appearance of sacculated dilatations of the canal of Petit.

The *canal of Petit* is the interval surrounding the edge of the lens-capsule, bounded in front by the suspensory ligament, and behind by the hyaloid membrane. Its width is about $\frac{1}{10}$th of an inch. On blowing air into it through an opening in the anterior boundary, the plaits of the suspensory ligament on its front are distended, and the canal presents a sacculated appearance.

AQUEOUS HUMOUR AND ITS CHAMBER.

The aqueous humour fills the space in the fore part of the eyeball, between the cornea and the capsule of the lens with its suspensory ligament. The iris, resting in part upon the lens, divides the aqueous chamber partially into two. The aqueous humour differs little from water in its physical characters; but it contains a small quantity of some solid matter, chiefly chloride of sodium, dissolved in it.

The chambers, into which the space containing the aqueous humour is divided by the iris, are named respectively the anterior and posterior. This subdivision is incomplete in the adult, but in the fœtus before the seventh month it is completed by means of the membrana pupillaris, which by its union with the margin of the pupil closes the aperture of communication between the two chambers.

The *anterior chamber* is limited in front by the cornea and behind by the iris, while opposite the pupil it is bounded by the capsule of the lens.

The *posterior chamber* was originally so named in the belief that a free space intervened between the iris and the capsule of the lens. It is now, however, well ascertained by observations on the living eye, and by sections made in the frozen state, that the pupillary margin and part of the posterior surface of the iris are in contact with the capsule of the lens; and the term posterior chamber can therefore be employed only to indicate the want of continuity between those opposed structures, where no space actually intervenes, and to the angular interval existing at the circumference between the ciliary processes, the iris, and the suspensory ligament.

DEVELOPMENT OF THE EYE.

The eyes begin to be developed at a very early period, in the form of two hollow processes projecting one from each side of the first primary cerebral vesicle. Each process becomes converted into a flask-shaped vesicle, called the *primary optic vesicle*, which communicates by a hollow pedicle with the base of the posterior division of the first primary cerebral vesicle. (See p. 578, and fig. 386 B.) According to the observations of Remak on the chick, the pedicles, originally separate, come together, and their cavities temporarily communicate,—a condition which may explain the formation of the optic commissure. The primary optic vesicle comes in contact at its extremity with the cuticle, which somewhat later becomes invaginated at this point, and forms a small pouch pressing inwards on the optic vesicle; the aperture of this

Fig. 490.

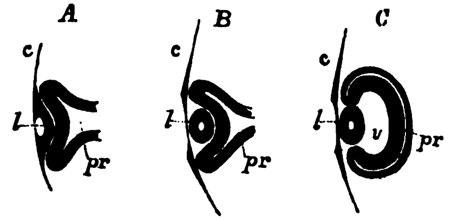


Fig. 490.—Longitudinal Section of the Primary Optic Vesicle in the Chick magnified (from Remak).

A, from an embryo of sixty-five hours; B, a few hours later; C, of the fourth day; *c*, the corneous layer or epidermis, presenting in A, the open depression for the lens, which is closed in B and C; *l*, the lens follicle and lens; *pr*, the primary optic vesicle; in A and B, the pedicle is shown; in C, the section being to the side of the pedicle, the latter is not shown; *v*, the secondary ocular vesicle and vitreous humour.

pouch becomes constricted and closed, and the pouch is soon converted into a shut sac, within which the contents subsequently becoming solid form the lens and its capsule. After the lens has been separated from the cuticle, the deeper tissue sends a

projection from below upwards between the lens and the optic vesicle, in such a manner as to invaginate the superficial and lower walls of the vesicle, pressing them upwards and inwards on the superior and deep walls, and giving them the form of a cup imperfect below, the *secondary optic vesicle*. The involution gives rise to the

Fig. 491.

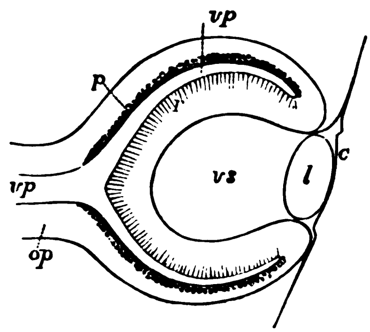


Fig. 491.—Diagrammatic Sketch of a Vertical Longitudinal Section through the Eyeball of a Human Fœtus of Four Weeks (after Kölliker). $\frac{100}{1}$

The section is a little to the side so as to avoid passing through the ocular cleft. *c*, the cuticle, where it becomes later the cornea; *l*, the lens; *op*, optic nerve formed by the pedicle of the primary optic vesicle; *vp*, primary medullary cavity or optic vesicle; *p*, the pigment layer of the choroid coat of the outer wall; *r*, the inner wall forming the retina; *vs*, secondary optic vesicle containing the rudiment of the vitreous humour.

cavity in which the vitreous humour is formed; and, the forepart of the optic nerve participating in the invagination, it is by this means that the central artery of the retina is introduced into the nerve and the eyeball, being, as it were, folded within them. The deficiency in the wall of the cup of the secondary vesicle inferiorly is

Fig. 492.

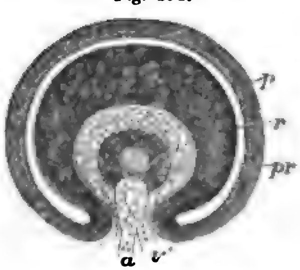


Fig. 492.—Transverse Vertical Section of the Eyeball of a Human Embryo of Four Weeks (from Kölliker). $\frac{100}{1}$

The anterior half of the section is represented. *pr*, the remains of the cavity of the primary optic vesicle; *p*, the inner part of the outer layer, forming the choroidal pigment; *r*, the thickened inner part giving rise to the columnar and other structures of the retina; *v*, the commencing vitreous humour within the secondary optic vesicle; *v'*, the ocular cleft through which the loop of the central bloodvessel, *a*, projects from below; *l*, the lens with a central cavity.

gradually filled up by the growing downwards of the edges, until only a cleft is left, which is discernible for a considerable time, and has been named the ocular cleft. The history of this cleft is of interest in connection with congenital fissure of the iris (coloboma iridis) and the accompanying condition of the choroid membrane. Some difference of opinion exists with regard to the subsequent history of the walls of the secondary vesicle, but the opinion of Kölliker appears to be well founded, that the invaginated layer forms the retina, and the outer part the pigmentary epithelium of the choroid. Thus the elements of Jacob's membrane and the hexagonal cells of the choroid may be regarded as originally continuous, forming together the epithelial lining of the cavity of the primary vesicle; and the development of nervous tissue underneath Jacob's membrane, while none exists beneath the choroidal layer, is a circumstance which may be looked upon as analogous to the absence of nervous tissue from various parts of the walls of the cerebral vesicles. The sclerotic coat and cornea are formed from the surrounding tissue external to the parts of the eye which they enclose; and, according to Kölliker, the vascular part of the choroid is of later formation. Still later, in the second month of fœtal life, the iris begins to be formed

as a septum projecting inwards from the forepart of the choroid coat, between the lens and the cornea.

Fig. 493.

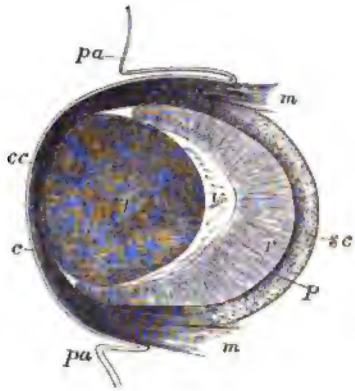


Fig. 493.—Vertical Longitudinal Section of the Eye of an Embryo Calf (from Kölliker). $\frac{64}{1}$

c, the cornea; *cc*, conjunctiva of the cornea; *l*, the lens; *v*, vitreous humour; *r*, retina; *p*, pigment layer of the choroid; *sc*, commencement of the sclerotic and choroid coats; *m*, superior and inferior recti muscles; *pa*, folds of integument forming the commencement of the upper and lower eyelids.

The crystalline lens in the fœtus is surrounded by a highly vascular tunic, supplied by a branch of the central artery of the retina, which passes forwards in the axis of the globe, and breaks up at the back of the lens into a brush of rapidly subdividing branches. The forepart of this tunic, adherent to the pupillary margin of the iris, forms the *pupillary membrane* by which the aperture of the pupil is closed. The whole tunic, however, together with the artery which supplies it, becomes atrophied, and is lost sight of before birth in the human subject, although in some animals it remains for a few days after. According to Kölliker, the anterior chamber is formed only a short time before birth by the intervention of the aqueous humour between the iris and cornea.

Fig. 494.

Fig. 494.—Bloodvessels of the Capsulo-Pupillary Membrane of a New-Born Kitten, magnified (from Kölliker).

The drawing is taken from a preparation injected by Tiersch, and shows in the central part the convergence of the network of vessels in the pupillary membrane.

The *eyelids* make their appearance as folds of integument, subsequent to the formation of the globe. When they have met together in front of the eye their edges become closely glued together; and they again open before birth.

The lachrymal canal may be regarded as a persistently open part of the fissure between the lateral frontal process and maxillary lobe of the embryo. (See p. 65, and fig. 56 B, 4, 6.)

THE EAR.

The organ of hearing is divisible into three parts: the external ear, the tympanum or middle ear, and the labyrinth or internal ear. The first two of these are to be considered as accessories or appendages to the third, which is the sentient portion of the organ.

Fig. 495.

Fig. 495.—Diagrammatic View from before of the Parts composing the Organ of Hearing of the Left Side (after Arnold).

The temporal bone of the left side, with the accompanying soft parts, has been detached from the head, and a section has been carried through it transversely so as to remove the front of the meatus externus, half the tympanic membrane, the upper and anterior wall of the tympanum and Eustachian tube. The meatus internus has also been opened, and the bony labyrinth exposed by the removal of the surrounding parts of the petrous bone. 1, the pinna and lobe; 2, 2′, meatus externus; 2′, membrana tympani; 3, cavity of the tympanum; 3′, its opening backwards into the mastoid cells; between 3 and 3′, the chain of small bones; 4, Eustachian tube; 5, meatus internus containing the facial (uppermost) and the auditory nerves; 6, placed on the vestibule of the labyrinth above the fenestra ovalis; *a*, apex of the petrous bone; *b*, internal carotid artery; *c*, styloid process; *d*, facial nerve issuing from the stylo-mastoid foramen; *e*, mastoid process; *f*, squamous part of the bone covered by integument, &c.

THE EXTERNAL EAR.

In the external ear are included the pinna,—the part of the outer ear which projects from the side of the head; together with the meatus or passage which leads thence to the tympanum, and is closed at its inner extremity by a membrane (membrana tympani) interposed between it and the middle ear.

THE PINNA.

Superficial configuration.—The general form of the pinna or auricle is concave, as seen from the outside, to fit it for collecting and concentrating the undulations of sound; it is thrown into various elevations and hollows, to which distinct names have been given. The largest and deepest concavity, a little below the centre of the organ, is called the *concha;* it

surrounds the entrance to the external auditory meatus, and is unequally divided at its upper part by a ridge, which is the beginning of the helix. In front of the concha, and projecting backwards over the meatus auditorius, is a conical prominence, the *tragus*, covered usually with hairs. Behind this, and separated from it by a deep notch (incisura intertragica), is another smaller elevation, the *antitragus*. Beneath the antitragus, and forming the lower end of the auricle, is the *lobule*, which is devoid of the firmness and elasticity that characterise the rest of the pinna. The thinner and larger portion of the pinna is bounded by a prominent and incurved margin, the *helix*, which, springing above and rather within the tragus, from the hollow

Fig. 496.

Fig. 496.—Outer Surface of the Pinna of the Right Auricle. ½

1, helix; 2, fossa of the helix; 3, antihelix; 4, fossa of the antihelix; 5, antitragus; 6, tragus; 7, concha; 8, lobule.

of the concha, surrounds the upper and posterior margin of the auricle, and gradually loses itself in the back part of the lobule. Within the helix is another curved ridge, the *antihelix*, which, beginning below at the antitragus, sweeps round the hollow of the concha, forming the posterior boundary of that concavity, and is divided superiorly into two diverging ridges. Between the helix and the antihelix is a narrow, curved groove, the *fossa of the helix* (fossa innominata, scaphoidea); and in the fork of the antihelix is a somewhat triangular depression, the *fossa of the antihelix* (fossa triangularis vel ovalis).

Structure.—The pinna consists of a thin plate of cartilage and of integument, with a certain amount of adipose tissue. It presents also several ligaments and small muscles of minor importance.

The *skin of the pinna* is thin, closely adherent to the cartilage, and contains sebaceous follicles, which are most abundant in the hollows of the concha and scaphoid fossa.

The *cartilage* presents all the inequalities of surface already described as apparent on the outer surface of the pinna; and on its cranial surface exhibits prominences the reverse of the concha and the fossa of the helix, while between these is a depression in the situation of the antihelix. This cartilage is not confined to the pinna, but enters likewise into the construction of the outer part of the external auditory canal. When dissected separate from other structures it is seen to be attached by fibrous tissue to the rough and prominent margin of the external auditory meatus of the temporal bone. The tubular part is cleft in front from between the tragus and fore part of the helix inwards to the bone, the deficiency being filled with fibrous membrane; thus the cartilage may be said to be a plate, a part of which assumes the tubular form by being folded so as to bring the upper margin, which lies in front of the tube of the ear, nearly into contact with the lower part, which being coiled inwards upon itself forms the upper border of the tragus. Following the free border of the plate backwards beneath the meatus, it is seen to pass round the lower margin of the concha, and to form the prominences of the tragus and antitragus, while the cartilage is absent alto-

gether from the lobule, which contains only fat and tough connective tissue. Behind the antitragus is a deep notch, separating it from the cartilage of the helix, which here forms a tail-like process descending towards the lobule. At the fore part of the pinna, opposite the first bend of the helix, is a small conical projection of the cartilage, called the *process of the helix*, to which the anterior ligament is attached. Behind this process is a short vertical slit in the helix; and on the surface of the tragus is a similar but somewhat longer fissure. A deep fissure passes back between the commencement of the helix and the tube of the ear, and another passing outwards and backwards from the deep end of the longitudinal cleft separates the part forming the tragus from the rest of the tube, so that the tube is continuous with the pinna only by means of a narrow isthmus. One or two other irregular gaps or fissures partially divide the cartilaginous tube transversely, and the whole of these deficiencies are termed *fissures of Santorini*. The substance of the cartilage is very pliable, and is covered by a firm fibrous perichondrium.

Of the *ligaments of the pinna*, the most important are two, which assist in attaching it to the side of the head. The *anterior* ligament, broad and strong, extends from the process of the helix to the root of the zygoma. The *posterior* ligament fixes the back of the auricle (opposite the concha) to the outer surface of the mastoid process of the temporal bone. A few fibres attach the tragus also to the root of the zygoma. Ligamentous fibres are likewise placed across the fissures and intervals left in the cartilage.

Of the *muscles of the pinna*, those which are attached by one end to the side of the head, and move the pinna as a whole, have been already described (p. 170): there remain to be examined several smaller muscles, composed of thin layers of pale fibres, which extend from one part of the pinna to another, and may be named the special muscles of the organ. Six small muscles are distinguished; four being placed on the outer and two on the inner or deep surface of the pinna.

The *smaller muscle of the helix* (m. minor helicis) is a small bundle of oblique fibres, lying over, and firmly attached to that portion of the helix which springs from the bottom of the concha.

Fig. 497.

Fig. 498.

Fig. 497.—Cartilage of the Pinna exposed, with the Muscles on its Outer Surface.

1, musculus helicis minor; 2, m. helicis major; 3, tragicus; 4, antitragicus.

Fig. 498.—Inner Surface of the Cartilage of the Pinna with the Small Muscles attached.

5, transversus auriculæ muscle; 6, obliquus auriculæ muscle.

The *greater muscle of the helix* (m. major helicis) lies vertically along the anterior margin of the pinna. By its lower end it is attached to the process of the helix; and above, its fibres terminate opposite the point at which the ridge of the helix turns backwards.

The *muscle of the tragus* (m. tragicus) is a flat bundle of short fibres covering the outer surface of the tragus : its direction is nearly vertical.

The *muscle of the antitragus* (m. antitragicus) is placed obliquely over the antitragus and behind the lower part of the antihelix. It is fixed at one end to the antitragus, from which point its fibres ascend to be inserted into the tail-like extremity of the helix, above and behind the lobule.

The *transverse muscle* (m. transversus auriculæ) lies on the inner or cranial surface of the pinna, and consists of radiating fibres which extend from the back of the concha to the prominence which corresponds with the groove of the helix.

The *oblique muscle* (Tod) consists of a few fibres stretching from the back of the concha to the convexity directly above it, across the back of the inferior branch of the antihelix, and near the fibres of the transverse muscle.

Arteries of the pinna.—The *posterior auricular* artery, a branch from the external carotid, is distributed chiefly on the posterior or inner surface, but sends small branches round and through the cartilage to ramify on the outer surface of the pinna. Besides this artery, the auricle receives others, the *anterior auricular* from the temporal in front, and a small artery from the occipital behind.

The *veins* correspond much in their course with the arteries. They join the temporal vein, and their blood is returned therefore through the external jugular.

Nerves of the pinna.—The *great auricular* nerve (p. 638), from the cervical plexus, supplies the greater part of the back of the auricle, and sends small filaments with the posterior auricular artery to the outer surface of the lobule and the part of the ear above it. The *posterior auricular* nerve, derived from the facial (p. 612), after communicating with the *auricular branch of the pneumogastric*, ramifies on the back of the ear and supplies the retrahent muscle. The upper muscles of the auricle receive their supply from the *temporal branches* of the same nerve. The *auriculo-temporal* branch of the third division of the fifth nerve (p. 606) gives filaments chiefly to the outer and anterior surface of the pinna.

THE EXTERNAL AUDITORY CANAL.

The external auditory canal (meatus auditorius externus) extends from the bottom of the concha to the membrane of the tympanum, and serves to convey to the middle chamber of the ear the vibrations of sound collected by the auricle. The canal is about one inch and a quarter in length. In

Fig. 499.

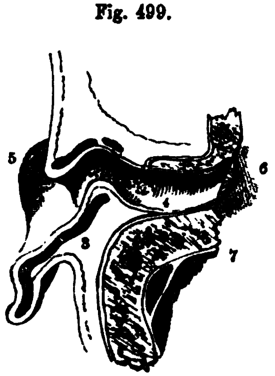


Fig. 499.—View of the Lower Half of the Auricle and Meatus in the Left Ear divided by a Horizontal Section (after Sömmerring).

1 and 2, cut surfaces of the bony part of the meatus ; 3, cut surface of the cartilage of the pinna ; 4, external meatus with the openings of numerous ceruminous glands indicated ; 5, lobule ; 6, membrane of the tympanum ; 7, dura mater lining the skull.

its inward course it is inclined somewhat forwards ; and it presents likewise a distinct vertical curve, being directed at first somewhat upwards, and afterwards turning somewhat abruptly over a convexity of the osseous part of its floor, and dipping downwards to its termination,—a change of direction which must be borne in mind by the surgeon in introducing specula into the ear. The

calibre of the passage is smallest about the middle. The outer opening is largest from above downwards, but the tympanic end of the tube is slightly widest in the transverse direction. At the inner extremity the tube is terminated by the membrana tympani, which is placed obliquely, with the inferior margin inclined towards the mesial plane, and thus the floor of the meatus is longer than its roof.

The meatus is composed of a tube partly cartilaginous and partly osseous, and is lined by a prolongation of the skin of the pinna.

The *cartilaginous* part of the meatus forms somewhat less than half the length of the passage. It is formed by the deep part of the cartilage of the pinna, which has been already described.

The *osseous portion* of the meatus is a little longer and rather narrower than the cartilaginous part. At its inner end it presents a narrow groove, which extends round the sides and floor of the meatus, but is deficient above; into this the margin of the membrana tympani is inserted.

The *skin* of the meatus is continuous with that covering the pinna, but is very thin, and becomes gradually thinner towards the bottom of the passage. In the osseous part of the canal it adheres very closely to the periosteum; and at the bottom of the tube this lining is stretched over the surface of the membrana tympani, forming the outer layer of that structure. After maceration in water, or when decomposition is advanced, the epidermic lining of the passage may be separated and drawn out entire, and then it appears as a small tube closed at one end somewhat like the finger of a glove. Towards the outer part the skin possesses fine hairs and sebaceous glands; and in the thick subdermic tissue over the cartilage are many small oval glands of a brownish-yellow colour, agreeing in form and structure with the sweat glands. The cerumen or ear-wax is secreted by these glands, *glandulæ ceruminosæ*, and their numerous openings may be seen to perforate the skin of the meatus. These accessory parts are absent over the bony part of the tube.

Vessels and nerves.—The external auditory meatus is supplied with arteries from the posterior auricular, internal maxillary and temporal arteries; and with nerves chiefly from the temporo-auricular branch of the fifth nerve.

State in the infant.—The auditory passage is in a very rudimentary state in the infant, for the osseous part begins to grow out of the tympanic bone only at the period of birth (p. 68), and thus the internal and middle parts of the ear are brought much closer to the surface than in the adult.

THE MIDDLE EAR OR TYMPANUM.

The tympanum or drúm, the middle chamber of the ear, is a narrow irregular cavity in the substance of the temporal bone, placed between the inner end of the external auditory canal and the labyrinth. It receives the atmospheric air from the pharynx through the Eustachian tube, and contains a chain of small bones, by means of which the vibrations communicated from without to the membrana tympani are in part conveyed across the cavity to the sentient part of the internal ear, and by which also pressure is maintained on the contents of the internal ear, varying in amount according to the tension of the membrana tympani. The tympanum contains likewise minute muscles and ligaments, which belong to the bones referred to, as well as some nerves which end within this cavity, or pass through it to other parts.

The cavity of the tympanum may be considered as presenting for con-

sideration a roof and a floor, an outer and an inner wall, and an anterior and a posterior boundary.

The *roof* of the tympanum is formed by a thin plate of bone, which may be easily broken through so as to obtain a view of the tympanic cavity from above; it is situated on the upper surface of the petrous portion of the temporal bone, near the angle of union with the squamous portion, from which in its development it is derived.

The *floor* is narrow, in consequence of the outer and inner boundaries being inclined towards each other.

The *outer wall* is mainly formed by a thin semitransparent membrane—membrana tympani, which closes the inner end of the external auditory meatus; and, to a small extent, by bone. Immediately in front of the ring of bone into which the membrana tympani is inserted, is the inner extremity of the fissure of Glasser, which gives passage to the laxator tympani muscle, and attachment to the processus gracilis of the malleus. Close to the back of this fissure is the opening of a small canal (named by Cruveilhier the canal of Huguier), through which the chorda tympani nerve usually escapes from the cavity of the tympanum and the skull.

Fig. 500.

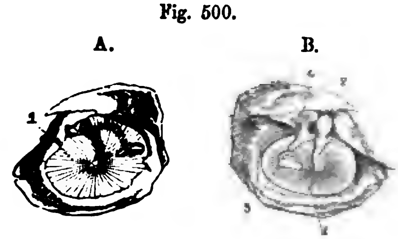


Fig. 500.—MEMBRANA TYMPANI AS SEEN FROM THE OUTER AND INNER SIDE.

A, the outer surface; B, the inner; in the latter the small bones are seen adherent to the membrane and adjacent parts of the temporal bone; in A, the shaded part indicates the small bones as partially seen through the membrane; 1, membrana tympani; 2, malleus; 3, stapes; 4, incus.

The *membrana tympani* is a nearly circular disc, slightly concave on its outer surface. It is inserted into the groove already noticed at the end of the meatus externus, and so obliquely that the membrane inclines towards the anterior and lower part of the canal at an angle of about 45°. The handle of the malleus, one of the small bones of the tympanum, descends between the middle and inner layers of the membrana tympani to a little below the centre, where it is firmly fixed; and as the direction of this process of the bone is slightly inwards, the outer surface of the membrane is thereby rendered concave, being held inwards in the shape of a shallow cone.

Though very thin, the membrana tympani is composed of three distinct structures. A prolongation of the skin of the external meatus forms the outer layer; the mucous membrane lining the cavity of the tympanum furnishes an inner layer; and between those two is the proper substance of the membrane, made up of fine fibrous and elastic tissues with vessels and nerves. The greater number of the fibres radiate from near the centre at the attachment of the handle of the malleus; but close to the circumference are some circular fibres, which form a dense, almost ligamentous ring.

The *inner wall* of the tympanum, which separates it from the internal ear, is very uneven, presenting several elevations and foramina. Near its upper part is an ovoid, or nearly kidney-shaped opening—*fenestra ovalis*, which leads into the cavity of the vestibule. This opening, the long diameter of

which is from before backwards, with a slight inclination downwards in front, is occupied in the recent state by the base of the stapes, and the annular ligament connected with that process of bone. Above the fenestra ovalis, and between it and the roof of the tympanum, a ridge indicates the position of the aqueduct of Fallopius, as it passes backwards, containing the portio dura of the seventh nerve. Below it is a larger and more rounded elevation, caused by the projection outwards of the first turn of the cochlea, and named the *promontory*, or tuber cochleæ; it is marked by grooves, in which lie the nerves of the tympanic plexus.

Fig. 501.

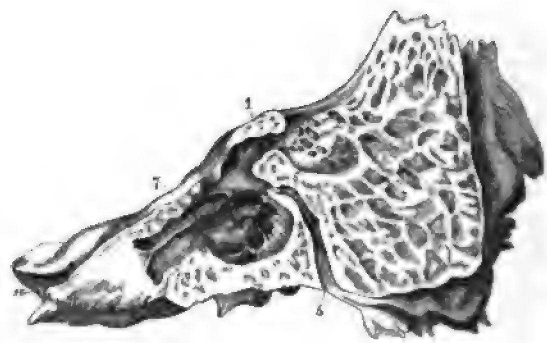


Fig. 501.—Inner Wall of the Osseous Tympanum as exposed by a Longitudinal Section of the Petrous and Mastoid Bone (from Gordon).

1, opening of the tympanum into the mastoid cells; 2, fenestra ovalis; 3, fenestra rotunda; 4, promontory; 5, aqueduct of Fallopius, or canal of the facial nerve; 6, junction of the canal for the chorda tympani with the aqueduct; 7, processus cochleariformis; 8, groove above it for the tensor tympani muscle; 9, Eustachian tube; 10, anterior orifice of the carotid canal.

Below and behind the promontory, and somewhat hidden by it, is a slightly oval aperture named *fenestra rotunda*, which lies within a funnel-shaped depression. In the macerated and dried bone the fenestra rotunda opens into the scala tympani of the cochlea; but, in the recent state it is closed by a thin membrane.

The membrane closing the fenestra rotunda—the *secondary membrane of the tympanum* (Scarpa)—is rather concave towards the tympanic cavity, and is composed of three strata like the membrana tympani; the middle layer being fibrous, and the outer and inner derived from the membranes lining the cavities between which it is interposed, viz., the tympanum and the cochlea.

The *posterior wall* of the tympanum presents at its upper part one larger, and several smaller openings, which lead into irregular cavities, the *mastoid cells*, in the substance of the mastoid process of the temporal bone. These cells communicate freely with one another, and are lined by mucous membrane continuous with that which clothes the tympanum. Behind the fenestra ovalis, and directed forwards, is a small conical eminence, called the *pyramid*, or eminentia papillaris. Its apex is pierced by a foramen, through which the tendon of the stapedius muscle emerges from a canal which turns downwards in the posterior wall of the tympanum, and joins obliquely the descending part of the aqueduct of Fallopius.

The *anterior extremity* of the tympanum is narrowed by the gradual descent of the roof, and is continued into the Eustachian orifice. The lower compartment of this orifice, lined with mucous membrane, forms the commencement of the Eustachian tube; the upper compartment, about half an inch long, lodges the tensor tympani muscle, and opens into the tympanum immediately in front of the fenestra ovalis, surrounded by the expanded and everted end of the cochleariform process, which separates it from the lower compartment.

Fig. 502.

Fig. 502.—Antero-posterior Section of the Temporal Bone, showing the Inner Wall of the Tympanum, with the Eustachian Tube and Small Bones in the Recent State (from Arnold).

1, styloid process; 2, mastoid process; 3, upper part of the petrous bone; 4, pharyngeal end of the Eustachian tube; 5, its cartilage; 6, its mucous surface; 7, carotid canal; 8, fenestra rotunda; 9, malleus; 10, incus; 11, stapes; 12, pyramid and stapedius muscle; above 9, and behind 10, the suspensory ligaments of the malleus and incus are also seen.

The *Eustachian tube* is a canal, formed partly of bone, partly of cartilage and membrane, which leads from the cavity of the tympanum to the upper part of the pharynx. From the tympanum it is directed forwards and inwards, with a little inclination downwards; and its entire length is about an inch and a half. The *osseous* division of the Eustachian tube, already described in the Osteology, is placed in the angle of junction of the petrous portion of the temporal bone with the squamous portion. The *anterior* part of the tube is formed of a triangular piece of cartilage, the edges of which are slightly curled round towards each other, leaving an interval at the under side, in which the canal is completed by dense but pliable fibrous membrane. Narrow behind, the tube gradually expands till it becomes wide and trumpet-shaped in front; and the anterior part is compressed from side to side, and is fixed to the inner pterygoid process of the sphenoid bone. The anterior opening is oval in form, and is placed obliquely at the side and upper part of the pharynx, into which its prominent margin projects behind the lower meatus of the nose, and above the level of the hard palate. Through this aperture the mucous membrane of the pharynx is continuous with that which lines the tympanum, and under certain conditions air passes into and out of that cavity.

SMALL BONES OF THE EAR.

Three small bones (ossicula auditûs) are contained in the upper part of the tympanum : of these, the outermost (malleus) is attached to the membrana tympani ; the innermost (stapes) is fixed in the fenestra ovalis ; and

Fig. 503.

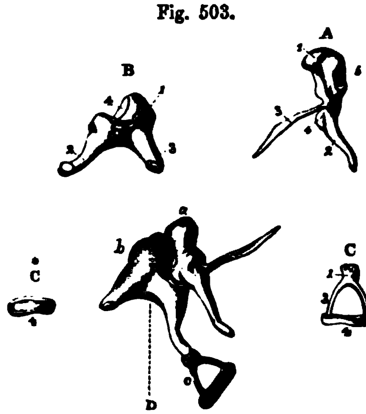


Fig. 503.—BONES OF THE TYMPANUM OF THE RIGHT SIDE (from Arnold). ‡

A, malleus ; 1, its head ; 2, the handle ; 3, long or slender process ; 4, short process ; B, incus ; 1, its body ; 2, the long process with the orbicular process ; 3, short or posterior process ; 4, articular surface receiving the head of the malleus ; C, stapes ; 1, head ; 2, posterior crus ; 3, anterior crus ; 4, base ; C*, base of the stapes ; D, the three bones in their natural connection as seen from the outside ; *a*, malleus ; *b*, incus ; *c*, stapes.

the third (incus), placed between the other two, is connected to both by articular surfaces. The malleus and incus are placed in nearly a vertical, the stapes in a horizontal direction. They form together an angular and jointed connecting rod between the membrana tympani and the membrane which closes the fenestra ovalis.

The *malleus*, or hammer bone, consists of a central thicker portion, with processes of different lengths. At the upper end of the bone is a rounded *head* (capitulum), which presents internally and posteriorly an irregularly oval surface covered with cartilage, for articulation with the incus. Below the head is a constricted *neck* (cervix) ; and beneath this another slight enlargement of the bone, to which the processes are attached. The *handle* (manubrium) of the malleus is a tapering and slightly twisted process, compressed from before backwards to near its point, where it is flattened in the opposite direction : it descends with a slight inclination forwards and inwards, and is received between the middle and inner layers of the membrana tympani, to which it is closely attached. The *long process* (processus gracilis) is a very slender spiculum of bone, which in the adult is usually broken off in its removal from the tympanum, in consequence of its union with the temporal bone ; it projects at nearly a right angle from the front of the neck of the malleus, and extends thence obliquely downwards and forwards to the Glasserian fissure. Its end is flattened and expanded, and is connected by ligamentous fibres and by bone to the sides of the fissure. The *short process* (processus brevis vel obtusus) is a low conical eminence springing from the root of the manubrium, beneath the cervix, and projecting outwards towards the upper part of the membrana tympani.

The *incus* has been compared to an anvil in form ; but it resembles perhaps more nearly a tooth with two fangs widely separated. It consists of a body and two processes. The *body* presents in front a concavo-convex articular surface, which is directed upwards and forwards, and receives the head of the malleus. The surfaces of the joint thus formed are tipped with articular cartilage and enclosed by a synovial membrane. The *shorter* of

the two processes (crus breve) of the incus projects nearly horizontally backwards from the upper part of the body of the bone, and is connected by ligamentous fibres with the posterior wall of the tympanum near the entrance of the mastoid cells. The *long process* (crus longum) tapers rather more gradually, and descends nearly vertically behind the handle of the malleus : at its extremity it is bent inwards, and is suddenly narrowed into a short neck ; and upon this is set a flattened rounded tubercle (processus lenticularis), tipped with cartilage. This tubercle, which articulates with the head of the stapes, was formerly, under the name of *os orbiculare seu lenticulare*, described as a separate bone, which indeed it originally is in childhood.

The *stapes*, the third and innermost bone of the ear, is in shape remarkably like a stirrup, and is composed of a head, a base, and two crura. The *head* is directed outwards, and has on its end a slight depression, covered with cartilage, which articulates with the lenticular process of the incus. The *base* is a plate of bone placed in the fenestra ovalis, to the margin of which it is fixed by ligamentous fibres. The form of the base is irregularly oval, the upper margin being curved, while the lower is nearly straight. The crura of the stapes diverge from a constricted part (*neck*) of the bone, situated close to the head, and are attached to the outer surface of the base near its extremities. The anterior crus is the shorter and straighter of the two. The crura, with the base of the stapes, enclose a small triangular or arched space, which in the recent state is occupied by a thin membrane stretched across. A shallow groove runs round the opposed surfaces of the bone, and into this the membrane is received.

LIGAMENTS AND MUSCLES OF THE TYMPANUM.

Ligaments.—In the articulations of the small bones of the ear with each other, the connection is strengthened by ligamentous fibres which cover the synovial membranes.

The attachment of the bones of the ear to the walls of the tympanum is effected partly by the reflections of the mucous membrane lining that cavity, but chiefly by muscles and by the following ligaments.

The *suspensory ligament of the malleus* consists of a small bundle of fibres, which descends perpendicularly from the roof of the tympanum to the head of the malleus.

The incus is likewise suspended by a small ligament (the *posterior ligament of the incus*), which extends from near the point of the short crus directly backwards towards the posterior wall of the tympanum, where it is attached near the entrance to the mastoid cells.

Arnold describes an upper ligament which attaches the incus, near its articulation with the malleus, to the roof of the tympanum. It lies close behind the suspensory ligament of the malleus.

The *annular* or *orbicular ligament of the stapes* connects the base of the bone to the margin of the fenestra ovalis, in which it is lodged.

Muscles.—There are three well-determined muscles of the tympanum. Sömmerring describes four, and some authors a larger number ; but their descriptions are not confirmed by later research. Of the three muscles generally recognised, two are attached to the malleus, and one to the stapes.

The *tensor tympani* (musculus internus mallei) is the largest of these muscles. It consists of a tapering fleshy part, about half an inch in length, and a slender tendon. The muscular fibres arise from the cartilaginous

end of the Eustachian tube and the adjoining surface of the sphenoid bone, and from the sides of the upper compartment of the Eustachian orifice. In this canal the muscle is conducted nearly horizontally backwards to the cavity of the tympanum. Immediately in front of the fenestra ovalis the tendon of the muscle bends at nearly a right angle over the end of the processus cochleariformis as through a pulley, and, contained in a fibrous sheath, passes outwards to be inserted into the inner part of the handle of the malleus, near its root.

Fig. 504.

Fig. 504.—View of the Cavity of the Right Tympanum from above.

The cavity of the tympanum and some parts of the labyrinth have been exposed by a horizontal section removing the upper part of the temporal bone. 1, posterior semicircular canal opened; 2, the cavity of the cochlea opened; 3, osseous part of the Eustachian tube; 4, head of the malleus; 5, incus; 6, stapes, with its base set in the fenestra ovalis; 7, tensor tympani muscle; 8, stapedius.

The *laxator tympani* (laxator tympani major of Sömmerring) is generally believed to be distinctly muscular, but being partly concealed by a band of fibrous tissue, doubts are still entertained by some observers as to whether the structure known under this name is of a muscular or ligamentous nature. Arising from the spinous process of the sphenoid bone, and slightly from the cartilaginous part of the Eustachian tube, it is directed backwards, passes through the Glasserian fissure, and is inserted into the neck of the malleus, just above the root of the processus gracilis.

The *laxator tympani minor* of Sömmerring (*posterior ligament of the malleus*, Lincke) is made up of reddish fibres, which are fixed at one end to the upper and back part of the external auditory meatus, pass forwards and inwards between the middle and inner layers of the membrana tympani, and are inserted into the outer border of the handle of the malleus, and the short process near it. Sömmerring. Icones Organi Auditûs Humani, 1801.

The *stapedius* is a very distinct muscle, but is hid within the bone, being lodged in the descending part of the aqueductus Fallopii and in the hollow of the pyramid. The tendon issues from the aperture at the apex of that little elevation, and passing forwards, surrounded by a fibrous sheath, is inserted into the neck of the stapes posteriorly, close to the articulation of that bone with the lenticular process of the incus.

A very slender spine of bone has been found occasionally in the tendon of the stapedius in man: and a similar piece of bone, though of a rounder shape, exists con-

stantly in the horse, the ox, and other animals. This circumstance is the more interesting when it is remembered that cartilage occupies the position of the stapedius before the muscle is developed. (P. 66 and fig. 528.)

Actions.—The malleus and incus move together round an axis extending backwards from the attachment of the processus gracilis of the malleus in the Glasserian fissure to the attachment of the short process of the incus posteriorly. The tendon of the tensor tympani muscle passing from within to be inserted below that line, pulls the handle of the malleus inwards, while the laxator tympani inserted above that line, by pulling the head of the bone inwards, moves the handle outwards. The incus, moving along with the malleus, pushes the stapes inwards towards the internal ear when the membrana tympani is made tight, and withdraws that bone from the fenestra ovalis, when the membrana tympani is relaxed. But the cavity of the inner ear is full of liquid; and its walls are unyielding, except at the fenestra rotunda; when, therefore, the stapes is pushed inwards the secondary membrane of the tympanum, which blocks up the fenestra rotunda, must be made tense by pressure from within. The attachment of the handle of the malleus, however, to the membrana tympani allows greater freedom of movement to that process than is allowed to the stapes by the ligament of its base, and when the movement of the stapes ceases, it is plain that the malleus in any movement must rotate on the head of the incus; and hence, probably, the necessity of a moveable articulation between those bones. The action of the stapedius muscle is obviously to draw the head of the stapes backwards, in doing which the hinder end of the base of that bone will be pressed against the margin of the fenestra ovalis, while the forepart will be withdrawn from the fenestra. The object gained by this movement of the stapes is not sufficiently ascertained; but it is at least evident that if the stapes be pressed inwards by the incus in the action of the tensor tympani, the stapedius muscle, if then contracted, will modify the pressure on the internal ear. It is conceivable that the stapedius may thus protect the sensitive part of the ear to a certain extent from excessive stimulation of the auditory nerve.

Fig. 505.

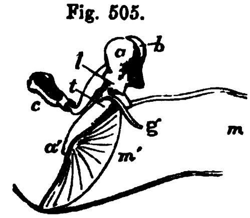


Fig. 505.—Outline of the Three Small Bones of the Left Ear as seen from before. $\frac{3}{1}$

This figure is designed to illustrate the effect of the action of the tensor and laxator muscles of the tympanic membrane in connection with their relation to the axis of rotation of the malleus. *a*, *a'*, the malleus; *b*, the incus seen behind it; *c*, the stapes; *m*, *m'*, the inner part of the meatus externus closed by the tympanic membrane, of which the posterior half is represented; the axis of rotation of the malleus being supposed to pass through a point at the root of the processus gracilis, *g*; the line *t*, indicates the direction and position of the tendon of the tensor tympani pulling the lower part of the malleus inwards, the line *l*, that of the laxator tympani pulling inwards the upper half of the malleus.

THE LINING MEMBRANE OF THE TYMPANUM.

The mucous membrane of the tympanum is continuous with that of the pharynx through the Eustachian tube, and is further prolonged from the tympanum backwards into the mastoid cells. Two folds which cross the breadth of the cavity descend from the part of the membrane which lines the roof. The anterior fold descends to turn round the tendon of the tensor tympani muscle; the posterior fold passes round the stapes. The malleus and incus are invested by the lining of the outer wall of the cavity. The mucous membrane which lines the cartilaginous part of the Eustachian tube resembles much the membrane of the pharynx, with which it is immediately continuous; it is thick and vascular, and is covered by several layers of laminar epithelium with vibratile cilia, and is provided with many simple mucous glands which pour out a thick secretion: in the osseous part of the

tube, however, this membrane becomes gradually thinner. In the tympanum and the mastoid cells it is paler, thinner and less vascular, and secretes a less viscid, but yellowish fluid. The epithelium in the tympanic cavity is also ciliated. The cilia, however, are usually absent from the part which lines the membrana tympani (Kölliker, Handbuch, p. 691).

THE VESSELS AND NERVES OF THE TYMPANUM.

The *arteries* of the tympanum, though very small, are numerous, and are derived from several branches of the external, and from the internal carotid.

The fore part of the cavity is supplied chiefly by the *tympanic branch* of the internal maxillary (p. 356), which enters by the fissure of Glasser. The back part of the cavity including the mastoid cells, receives its arteries from the *stylo-mastoid branch* of the posterior auricular artery (p. 353), which is conducted to the tympanum by the aqueduct of Fallopius. These two arteries form by their anastomosis a vascular circle round the margin of the membrana tympani. The smaller arteries of the tympanum are, the *petrosal branch* of the middle meningeal, which enters through the *hiatus Fallopii*; branches through the bone from the *internal carotid* artery, furnished from that vessel whilst in the carotid canal; and occasionally a twig along the Eustachian tube from the *ascending pharyngeal* artery.

The *veins* of the tympanum pour their contents through the middle meningeal and pharyngeal veins, and through a plexus near the articulation of the lower jaw, into the internal jugular vein.

Nerves.—The tympanum contains numerous nerves; for, besides those which supply the parts of the middle ear, there are several which serve merely to connect nerves of different origin.

The lining membrane of the tympanum is supplied by filaments from the plexus (tympanic plexus), which occupies the shallow grooves on the inner wall of the cavity, particularly on the surface of the promontory.

The *tympanic plexus* is formed by the communications between, 1st, the *tympanic branch* (nerve of Jacobson) from the petrous ganglion of the glosso-pharyngeal; 2nd, a *filament from the carotid plexus* of the sympathetic; 3rd, a branch which joins the *great superficial petrosal nerve*, from the Vidian; 4th and lastly, the *small superficial petrosal nerve*, from the otic ganglion.

Fig. 506.

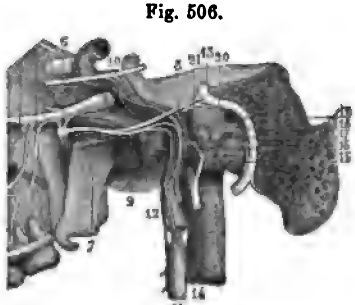


Fig. 506.—View of the Tympanic Plexus of Nerves (after Hirschfeld and Leveillé).

6, spheno-palatine ganglion; 7, Vidian nerve; 8, great superficial petrosal nerve; 9, carotid branch of the Vidian nerve; 10, part of the sixth nerve connected by twigs with the sympathetic; 11, superior cervical ganglion of the sympathetic; 12, carotid branch; 13, facial nerve; 14, glosso-pharyngeal nerve; 15, nerve of Jacobson; 16, its twig to the sympathetic; 17, filament to the fenestra rotunda; 18, filament to the Eustachian tube; 19, filament to the fenestra ovalis; 20, union of external deep petrosal nerve with the lesser superficial petrosal; 21, internal deep petrosal twig uniting with the great superficial petrosal.

The nerve of Jacobson enters the tympanum by a small foramen near its floor, which forms the upper end of a short canal in the petrous portion of the temporal bone, beginning at the base of the skull between the carotid foramen and the jugular

fossa. The nerve from the carotid plexus is above and in front of this, and passes through the bone directly from the carotid canal. The branch to the great superficial petrosal nerve is lodged in a canal which opens on the inner wall of the tympanum in front of the fenestra ovalis. The small superficial petrosal nerve also enters at the fore part of the cavity beneath the canal for the tensor tympani.

Nerves to Muscles.—The tensor tympani muscle obtains its nerve from the otic ganglion (*see* fig. 410); the laxator tympani is said to be supplied by the chorda tympani: and the stapedius is figured by Sömmerring as receiving a filament from the facial nerve.

The *chorda tympani* is invested by a tubular reflection of the lining membrane of the tympanum; its course across the cavity has already been described (p. 611).

THE INTERNAL EAR, OR LABYRINTH.

The inner, or sensory part of the organ of hearing, is contained in the petrous portion of the temporal bone. It consists of a cavity—the osseous labyrinth—hollowed out of the bone, and of the membranous labyrinth contained within the osseous walls.

Fig. 507.

Fig. 507.—Right Bony Labyrinth, viewed from the Outer Side (after Sömmerring). $\frac{2\frac{1}{2}}{1}$

The specimen here represented is prepared by separating piecemeal the looser substance of the petrous bone from the dense walls which immediately enclose the labyrinth. 1, the vestibule; 2, fenestra ovalis; 3, superior semicircular canal; 4, horizontal or external canal; 5, posterior canal; *, ampullæ of the semicircular canals; 6, first turn of the cochlea; 7, second turn; 8, apex; 9, fenestra rotunda. The smaller figure in outline below shows the natural size.

The *osseous labyrinth* is incompletely divided into three parts, named the vestibule, the semicircular canals, and the cochlea. They are lined throughout by a thin membrane, within which there is a clear fluid named perilymph.

The *membranous labyrinth* is contained within the bony labyrinth, and, being smaller than it, leaves a space between the two, occupied by the perilymph just referred to. The membranous structure supports numerous minute ramifications of the auditory nerve, and encloses a fluid named the endolymph.

THE OSSEOUS LABYRINTH.

The *vestibule* forms a central chamber of the labyrinth, which communicates in front with the cochlea, behind with the semicircular canals, on the outer side with the cavity of the tympanum, and on the inner side with the meatus auditorius internus. The vestibule is irregularly ovoidal in shape from before backwards, and is slightly flattened or compressed from without

inwards: except in the last-mentioned direction in which it is somewhat smaller, it measures about $\frac{1}{5}$th of an inch in diameter.

The outer wall, which separates it from the cavity of the tympanum, is perforated by the fenestra ovalis, which in the recent state is closed by the base of the stapes and its annular ligament.

At the fore part of the inner wall is a small round pit, the *fovea hemispherica*, pierced with many small holes, which serve to transmit branches of the auditory nerve from the internal auditory meatus. This fossa is limited behind by a vertical ridge named *crista vestibuli* or eminentia pyramidalis. Behind the crest is the small oblique opening of a canal, the *aqueduct of the vestibule*, which extends to the posterior surface of the bone, and transmits a small vein in a tubular prolongation of membrane.

In the roof is an oval depression, placed somewhat transversely, *fovea hemi-elliptica*, whose inner part is separated by the crest from the hemispherical fossa.

At the back part of the vestibule are five round apertures, leading into the semicircular canals: and at the lower and fore part of the cavity is a larger opening, which communicates with the scala vestibuli of the cochlea—*apertura scalæ vestibuli*.

The *semicircular canals* are three bony tubes, situate above and behind the vestibule, into which they open by five apertures, the contiguous ends of two of the canals being joined. They are unequal in length, but each tube is bent so as to form about two-thirds of a circle; and each presents, at one end, a slightly dilated part, called the *ampulla*. The canals are compressed laterally, and measure across about $\frac{1}{20}$th of an inch; but in the ampulla each has a diameter of $\frac{1}{10}$th of an inch.

Fig. 508.

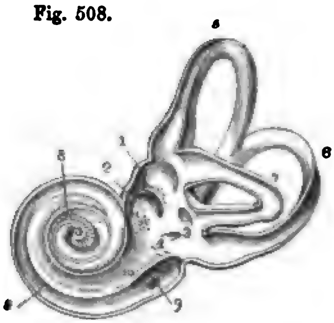


Fig. 508.—View of the Interior of the Left Labyrinth (from Sömmerring). $\frac{24}{1}$

The bony wall of the labyrinth is removed superiorly and externally. 1, fovea hemi-elliptica; 2, fovea hemispherica; 3, common opening of the superior and posterior semicircular canals; 4, opening of the aqueduct of the vestibule; 5, the superior, 6, the posterior, and 7, the external semicircular canals; 8, spiral tube of the cochlea (scala tympani); 9, opening of the aqueduct of the cochlea; 10, placed on the lamina spiralis in the scala vestibuli.

The canals differ from one another in position with regard to the vestibule, in direction, and in length. The *superior* semicircular canal is *vertical* and transverse; and, rising above any other part of the labyrinth, its place is indicated by a smooth arched projection on the upper surface of the bone. The ampullary end of this canal is the anterior, and opens by a distinct orifice into the upper part of the vestibule; whilst the opposite extremity joins the non-dilated end of the posterior semicircular canal, and opens by a common aperture with it into the back part of the vestibule. The *posterior* semicircular canal, *vertical* and longitudinal in direction, is the longest of the three tubes: its ampullary end is placed at the lower and back part of the vestibule; and the opposite end joins in the common canal above described. The *external* semi-

circular canal arches *horizontally* outwards, and opens by two distinct orifices into the upper and back part of the vestibule. This canal is shorter than either of the other two: its ampulla is at the outer end, just above the fenestra ovalis.

Fig. 509.

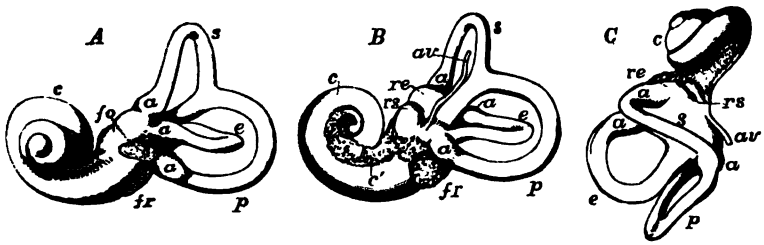


Fig. 509.—VIEWS OF A CAST OF THE INTERIOR OF THE LABYRINTH (from Henle). ½

Such casts may easily be made in fusible metal, and give a very correct view of the form of the different parts of the labyrinthic cavity. A, view of the left labyrinth from the outer side; B, the right labyrinth from the inner side; C, the left labyrinth from above; *s*, the superior, *p*, the posterior, and *e*, the external semicircular canals; *a*, their several ampullæ; *re*, fovea hemi-elliptica of the vestibule; *rs*, fovea hemispherica; *av*, aqueduct of the vestibule; *fo*, fenestra ovalis; *fr*, fenestra rotunda; *c*, the coiled tube of the cochlea; *c'*, the first part of the tube towards the base with the tractus foraminosus spiralis.

The *cochlea* is the most anterior division of the internal ear. When the dense bony substance, in which it lies embedded, is picked away, the cochlea presents the form of a blunt cone, the base of which is turned towards the internal auditory meatus, whilst the apex is directed outwards, with an inclination forwards and downwards, and is close to the canal for the tensor tympani muscle. It measures about a quarter of an inch in length, and the same in breadth at the base. The osseous part of the cochlea consists of a gradually tapering spiral tube, the inner wall of which is formed by the central columm, or *modiolus*, round which it winds, and which is partially divided along its whole extent by a spiral lamina projecting into it from the modiolus. From this osseous spiral lamina membranous structures are stretched across to the outer wall of the tube, and thus are completely separated two passages or scalæ, one on each side of the spiral lamina, which communicate one with the other by only a small opening, named *helicotrema*, placed at the apex of the cochlea.

Fig. 510.

Fig. 510.—OSSEOUS LABYRINTH OF THE BARN-OWL (STRIX FLAMMEA) (from Breschet). ½

1, semicircular canals; 2, vestibule; 3, cochlea in the form of a short straight tube.

That the cochlea is justly to be considered as an elongated tube, coiled spirally on the modiolus, is illustrated by the simple pouch-like form of the rudimentary cochlea of birds.

The *spiral canal of the cochlea* is about an inch and a half long, and about the tenth of an inch in diameter in its widest part at the commence-

ment. From this point the canal makes two turns and a half round the central pillar (from left to right in the right ear, and in the opposite direction in the left ear), and ends by an arched and closed extremity called the *cupola*, which forms the apex of the cochlea. The first coil, being much the widest in its curve and composed of the largest portion of the tube, nearly hides the second turn from view; and, bulging somewhat into the tympanum, forms the round elevation on the inner wall of that cavity called the promontory.

Fig. 511.

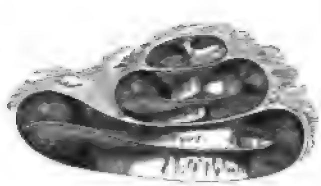


Fig. 512.

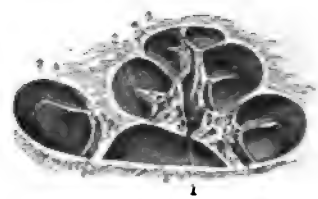


Fig. 511.—Diagrammatic View of the Canal of the Cochlea laid open. ½

1, modiolus or central pillar; 2, placed on three turns of the lamina spiralis; 3, scala tympani; 4, scala vestibuli.

Fig. 512.—View of the Osseous Cochlea divided through the Middle (from Arnold). ½

1, central canal of the modiolus; 2, lamina spiralis ossea; 3, scala tympani; 4, scala vestibuli; 5, porous substance of the modiolus near one of the sections of the canalis spiralis modioli.

The *modiolus* (columella cochleæ) forms the central pillar or axis round which turn the spiral tube and the spiral lamina. It is much thickest within the first turn of the cochlea, and rapidly diminishes in size in the succeeding parts. The outer surface is dense, being, in fact, composed of the walls of the spiral tube; but the centre is soft and spongy as far as the last half coil, and is pierced by many small canals for the passage of the nerves and vessels to the lamina spiralis: one of these canals, larger than the rest (*canalis centralis modioli*), runs from the base through the centre of the modiolus.

The *lamina spiralis ossea* is a thin, flat plate, growing from and winding round the modiolus, and projecting into the spiral tube, so as to divide it partly into two. Its free margin, which gives attachment in the recent state to the membranous septum, or zone, does not reach farther than about half of the distance between the modiolus and the outer wall of the spiral tube. The osseous lamina terminates close to the apex of the cochlea in a hook-like process (hamulus), which partly bounds the helicotrema.

The lamina is thin and dense towards its free margin; but near the modiolus it is composed of two dense outer plates enclosing a more open and spongy structure, in which are numerous small canals, continuous, but running at right angles with the canals in the centre of the modiolus. In these the nerves and vessels are lodged: they terminate on the inferior or tympanic aspect of the lamina, and the line of their orifices forms the *tractus foraminosus spiralis*. Winding round the modiolus, close to the lamina spiralis, is a small canal, named by Rosenthal the *canalis spiralis modioli*.

The *scalæ* in the osseous cochlea are two in number, distinguished as the scala tympani and scala vestibuli.

The *scala tympani*, the portion of the tube on the basal side of the lamina spiralis, commences at the fenestra rotunda, where in the recent state it is

separated from the tympanum by the secondary membrana tympani. Near its commencement is the orifice of a small canal, *aqueductus cochleæ*, which extends downwards and inwards through the substance of the petrous part of the temporal bone to near the jugular fossa, and transmits a small vein. The surface of the spiral lamina which looks towards this scala is marked with numerous transverse striæ. The *scala vestibuli* is rather narrower than the scala tympani in the first turn of the cochlea; it commences from the cavity of the vestibule, and communicates, as already described, with the scala tympani at the apex of the modiolus.

The lining membrane of the osseous labyrinth.—This is a thin membrane (periosteum?), which closely adheres to the whole inner surface of the several parts of the labyrinthic cavity just described. It has no continuity with the lining membrane of the tympanum, being stretched across the openings of the round and oval fenestræ. It is composed of fibres of connective tissue. Its outer surface is rough, and adheres closely, like periosteum, to the bone: the inner surface is pale and smooth, is covered with a single layer of epithelium, like that of the arachnoid, and secretes a thin, slightly albuminous or serous fluid. This secretion, known as the *liquor Cotunnii*, or *perilymph*, separates the membranous from the osseous labyrinth in the vestibule and semicircular canals, occupies the cavities of the scala tympani and scala vestibuli in the cochlea, and is continued into the aqueducts as far as the membrane lining these passages remains pervious.

THE MEMBRANOUS LABYRINTH.

Within the osseous labyrinth, and separated from its lining membrane by the perilymph, membranous structures exist in which the ultimate ramifications of the auditory nerve are spread. In the vestibule and semicircular canals these structures have a general resemblance in form to the complicated cavity in which they are contained. In the cochlea they complete the septum between the scalæ already mentioned, and enclose a third spiral passage, the canalis membranacea, the existence of which has only been discovered of late years. The liquid contained within the membranous labyrinth is distinguished as *endolymph*.

VESTIBULE.—The *membranous vestibule* consists of two closely connected sacs, and the parts by which they are united to the membranous semicircular canals and canal of the cochlea.

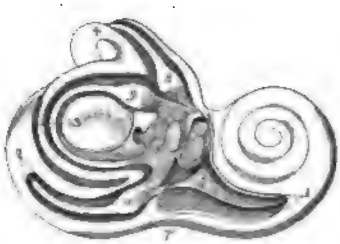
The larger of the two sacs, the *common sinus* or *utricle*, is of an oblong form, and slightly flattened from without inwards. It is lodged in the upper and back part of the osseous vestibule, occupying the fovea hemielliptica. Opposite the crista vestibuli several small branches of the auditory nerve enter from the foramina in the bone; and here the walls of the common sinus are thicker and more opaque than elsewhere. The extremities of the membranous semicircular canals terminate in the cavity of the common sinus. A small mass of calcareous particles, *otoliths* or *otoconia*, is lodged in the wall of the sac. These otoliths are crystals of carbonate of lime, and are described as six-sided, and pointed at their extremities. They are connected with the wall of the sac in a way not yet clearly determined.

The smaller vestibular vesicle, the *saccule*, is more nearly spherical than the common sinus, but, like it, is somewhat flattened. The saccule is situated in the lower and fore part of the cavity of the osseous vestibule, close to the opening from the scala vestibuli of the cochlea, and is received into the

hollow of the fovea hemispherica, from the bottom of which many branches of nerve enter. The sacculus appears to have a cavity distinct from that of the utricle, but is filled with the like thin and clear fluid, *endolymph*, and contains similar otoconia in its wall. It is prolonged below into a short narrow duct, canalis reuniens, which opens abruptly into the membranous canal of the cochlea.

Fig. 513.

A.



B.

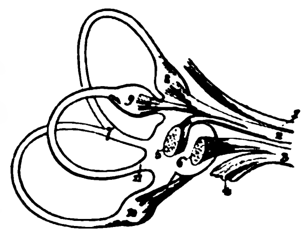


Fig. 513.—Views of the Interior of the Right Labyrinth with its Membranous Parts and Nerves (from Breschet). $\frac{3}{1}$

A, the outer wall of the osseous labyrinth in part removed so as to display the membranous parts within. 1, commencement of the spiral tube of the cochlea ; 2, posterior semicircular canal partially opened, showing its membranous canal and ampulla ; 3, external or horizontal canal entirely opened ; 4, superior canal ; 5, utriculus or common sinus with its group of otoliths ; 6, saccule with its otoliths ; 7, placed on the lamina spiralis in the commencement of the scala vestibuli ; 7′, scala tympani ; 8, membranous ampulla of the superior semicircular canal ; 9, ampulla of the horizontal, and 10, that of the posterior semicircular canal.

B, membranous labyrinth and nervous twigs detached ; 1, facial nerve in the meatus auditorius internus ; 2, anterior division of the auditory nerve giving branches to 5, 8, and 9, the utricle and the ampullæ of the superior and external canals ; 3, posterior division of the auditory nerve, giving branches to the saccule ; 6, posterior ampulla, 10, and cochlea, 4 ; 7, the united part of the superior and posterior canals ; 11, the posterior extremity of the external canal.

Semicircular Canals.—The *membranous semicircular canals* are about one third the diameter of the osseous tubes in which they are lodged, and are dilated into ampullæ within the ampullary enlargements of those tubes. At the ampullæ they are thicker and less translucent than in the rest of their extent, and nearly fill their bony cases. That part of each ampulla which is towards the concavity of the semicircle of the canal is free ; whilst the opposite portion is flattened, receives branches of nerves and blood-vessels, and presents on its inner surface a transverse projection, *septum transversum*, which partly divides the cavity into two. The ampullæ likewise contain otoliths in their epithelial lining.

Auditory nerve : vestibular division.—At the bottom of the meatus auditorius internus the auditory nerve divides into an anterior and a posterior branch, which, broken up into minute filaments, pass through the perforations of the cribriform plate which separates the meatus from the internal ear, and are distributed respectively to the cochlea and vestibule. In both branches, as well as in the trunk, there are numerous nerve-cells, apparently both with and without poles. The *vestibular nerve* divides into five branches, which proceed respectively to the utricle, the saccule, and the three ampullæ of the semicircular canals : those for the utricle and the superior and external semicircular canals enter the cavity in a group along the crista vestibuli ; the fibrils for the sacculus enter the vestibule by a

smaller group of foramina, which are situated below those just described, and open at the bottom of the fovea hemispherica; the branch for the posterior semicircular canal is long and slender, and traverses a small passage

Fig. 515.

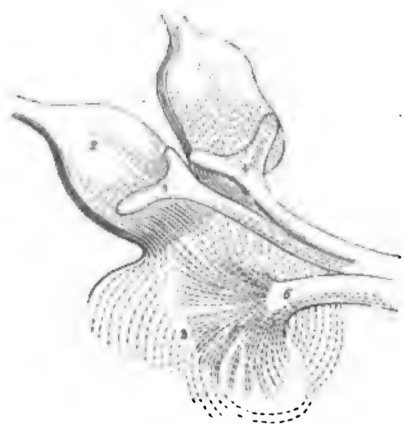


Fig. 514.

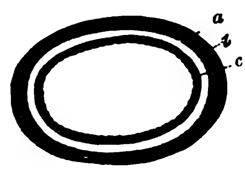


Fig. 514.—Transverse Section of one of the Membranous Semicircular Canals (from Kölliker). $\frac{250}{1}$

This specimen is from the ear of the calf: *a*, external fibrous layer with interspersed nuclei; *b*, homogeneous layer; *c*, epithelial lining.

Fig. 515.—Ampullæ of the Superior and External Semicircular Canals and Part of the Common Sinus showing the Arrangement of the Nerves (from Steifensand). $\frac{20}{1}$

1, membranous ampulla of the superior canal; 2, that of the external canal; 3, part of the common sinus; 4 and 5, fork-like swellings of the nerves at their ampullar distribution; 6, twig of the auditory nerve spreading in the common sinus.

in the bone behind the foramina for the nerve of the sacculus. The nerves of the ampullæ enter the flattened or least prominent side of the ampullæ where they each form a forked swelling, which corresponds with the transverse septum already described, in the interior of the dilatation. No filaments have been found extending to any other parts of the semicircular canals.

Microscopic structure.—The walls of the common sinus, sacculus and membranous semicircular canals are in general semitransparent; but they are thicker and more opaque where nerves and vessels enter. On the outer surface is a layer of minutely ramified blood-vessels and loose tissue, which contains irregular pigment-cells: within this is a transparent layer, faintly fibrillated, and presenting elongated nuclei when acetic acid is added: lining the interior is an epithelial layer of polygonal nucleated cells. The mode of ending of the nerves in the membranous substance of the vestibule and semicircular canals is difficult to investigate, on account of the minuteness and delicacy of the parts; for this reason also observers have had recourse in great measure to the examination of the vestibule and semicircular canals in fishes, in which they are of large size. The subject still requires further research, but it appears to be pretty certain

from the observations of Reich, the successive papers of M. and F. E. Schultze, and the corroborating observations of Kölliker, that the nerve fibres break up in the transparent layer into minute ramifications, which enter the epithelium and form between the epithelial cells spindle-shaped nucleated bodies with elongated extremities. There have also been observed long hair-like processes, *fila acustica*, projecting into the cavity, beyond the epithelial surface of the ridge of the ampullæ, and likewise in the sacs; and the actual continuity of these hairs with the nerve terminations has been in one instance observed by F. E. Schultze. According to Lang the hairs are only the altered remains of a delicate cap of tissue on the surface of the epithelium.—(Kölliker's Gewebelehre, 4th ed., p. 694.)

Fig. 516.

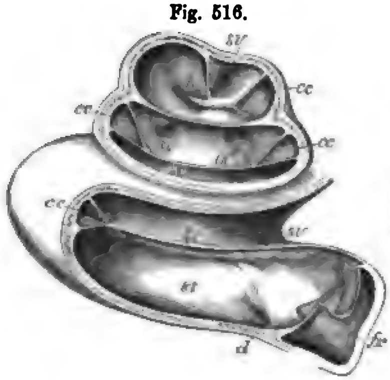


Fig. 517.

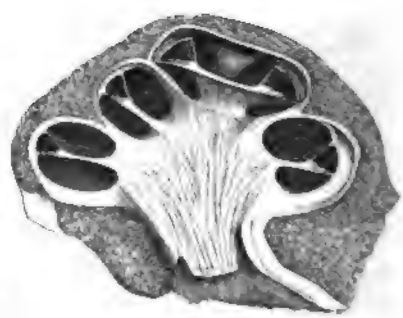


Fig. 516.—Left Cochlea of a Child some Weeks Old, opened (from Reichert). $\frac{3}{1}$

The drawing was taken from a specimen which had been preserved in alcohol, and was afterwards dried: the section is made so as to show the lamina spiralis, scalæ, and cochlear canal in each of the three coils: the membranous spiral lamina is preserved, but the appearances connected with the organ of Corti, &c., have been lost from drying. *fr*, fenestra rotunda with its membrane; *st*, scala tympani; *sv*, scala vestibuli; *ls*, lamina spiralis; *h*, hamulus; *cc*, canalis cochleæ; *d*, opening of the aqueductus cochleæ.

Fig. 517.—Vertical Section of the Cochlea of a Fœtal Calf (from Kölliker). $\frac{3}{1}$

In this specimen the external wall was ossified, but the modiolus and spiral lamina were still cartilaginous; the section shows in each part of the cochlear tube the two scalæ with the intermediate canalis cochleæ and lamina spiralis; the radiating lines in the modiolus indicate the passage of the auditory nerves towards the spiral lamina.

Cochlea.—The *membranous cochlea* has the form of a three-sided tube, the canalis membranacea, interposed between the scala vestibuli and the scala tympani. The peripheral wall of this canal is formed by part of the osseous cochlea, and on its other sides it is bounded by the basilar membrane and membrane of Reissner respectively, while at its inner angle is a structure named limbus laminæ spiralis, and in its interior, resting on the basilar membrane, is the organ of Corti with the membrana tectoria covering it. Each of these parts requires description.

The *membrana basilaris*, or *lamina spiralis membranacea*, is stretched across from the free margin (labium tympanicum) of the osseous lamina to the outer part of the spiral canal, lying in the same plane as the osseous lamina, and attached peripherally through the medium of a thick structure,

the *spiral ligament*. It increases in breadth from the base to the apex of the cochlea, while the osseous spiral lamina diminishes in breadth. Thus in the first turn of the cochlea this membrane forms about half of the breadth of the septum made by it and the osseous lamina; but towards the apex of the cochlea the proportion between the two parts is gradually reversed, until, near the helicotrema, the membranous part is left almost unsupported by any plate of bone.

Fig. 518.

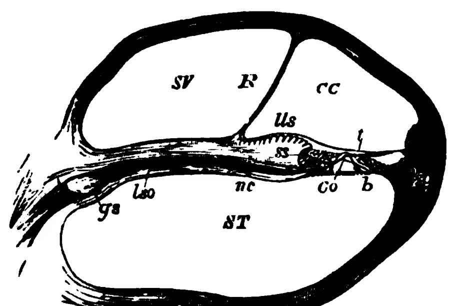


Fig. 518.—SECTION THROUGH ONE OF THE COILS OF THE COCHLEA (altered from Henle). $\frac{20}{1}$

A, the section is made in a specimen softened by immersion in hydrochloric acid; ST, scala tympani; SV, scala vestibuli; CC, canalis cochleæ; R, membrane of Reissner forming its vestibular wall; *lso*, lamina spiralis ossea; *lls* to *lsp*, lamina spiralis membranacea; *lls*, limbus laminæ spiralis; *ss*, sulcus spiralis; *nc*, twigs of cochlear nerve; *gs*, ganglion spirale; *t*, membrana tectoria; *b*, membrana basilaris; *Co*, organ of Corti; *lsp*, ligamentum spirale.

The *limbus laminæ spiralis* (denticulate lamina of Todd and Bowman) is a thick periosteal development near the edge of the osseous spiral lamina on the side which looks towards the vestibular scala. It makes a somewhat convex elevation, presenting externally a sharp margin which overhangs that to which the basilar membrane is attached, being separated from it by a groove. The groove is termed *sulcus spiralis*, and the margins *labium vestibulare* and *labium tympanicum* respectively. The *membrane of Reissner* (membrana vestibularis) arises from the inner part of the limbus, and extends outwards at a considerable angle with the osseous spiral lamina.

The *membrana tectoria* (Claudius), or membrane of Corti (Kölliker), has been variously described, but, according to the most recent researches, is an elastic membrane attached on its one border close to the membrane of Reissner, and on the other by an extremely delicate portion to the peripheral wall of the cochlea, a little above the membrana basilaris (Claudius and Henle). It thus divides the canalis membranacea into two parts: the large part placed between it and the membrane of Reissner, and containing endolymph; the other, a narrow interval dividing it from the membrana basilaris, and occupied by various cellular and rod-like structures of a highly complicated description, which together are designated as the *organ of Corti*.

The *canalis membranacea*, or *ductus cochlearis*, bounded in the manner already described, presents a blind pointed extremity at the apex and another at the base. That at the apex extends beyond the hamulus, fixed to the wall of the cupola, and partly bounding the helicotrema; that at the base fits into the angle at the commencement of the osseous spiral lamina in front of the floor of the vestibule. Near to this blind extremity the canalis membranacea receives a small duct, *canalis reuniens* (Hensen), which is continued downwards from the saccule of the vestibule like the

neck of a flask, and enters the membranous canal abruptly nearly at a right angle to it. Thus the cavity of the canalis membranacea is rendered continuous with that of the saccule.

Fig. 519.

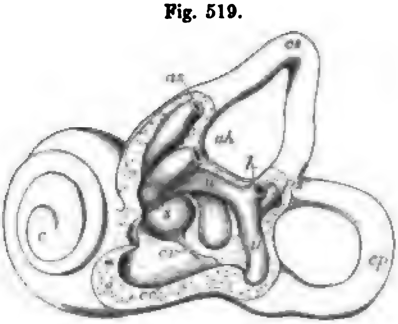


Fig. 519.—The Left Labyrinth of a Child at Birth, partially opened on its outer side to show the commencement of the Membranous Canal of the Cochlea (slightly altered after Reichert). ⅓

The external or horizontal canal has been removed; *cs*, superior canal; *cp*, posterior canal; *as*, membranous ampulla and tube of the superior canal cut short; *ah*, that of the external or horizontal canal; *h*, undilated end of the horizontal canal in front of the common opening of the superior and posterior canals; *ps*, united superior and posterior canals; *u*, utriculus; *s*, sacculus; *cc*, vestibular part or commencement of the membranous canal of the cochlea; *cr*, canalis reuniens connecting it with the sacculus; *c*, cochlea.

It is necessary to explain that although the canalis membranacea was described by Reissner so long ago as in 1851, yet, owing to some confusion having arisen between the membrane of Reissner and the membrana tectoria described by Corti, whose work appeared at the same time, the nature of this canal has until comparatively

Fig. 520.

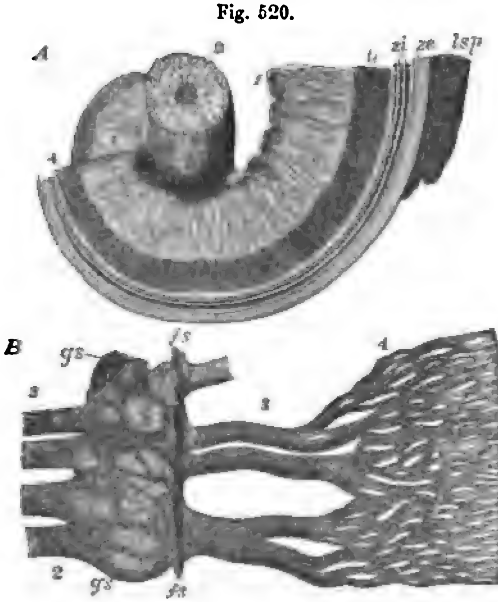


Fig. 520.—Distribution of the Cochlear Nerves in the Lamina Spiralis (after Henle).

A, part of the modiolus and spiral lamina showing the cochlear nerves forming a network, viewed from the base; 1, the twigs of the nerve issuing from the tractus spiralis foraminosus; 2, the branches of the nerve entering by the central canal of the modiolus; 3, wide plexus in the bony lamina spiralis; 4, close plexus at its border; *lt*, labium tympanicum; *zi*, zona interna; *ze*, zona externa; *lsp*, ligamentum spirale. B, part of the nerves extracted and more highly magnified; 2, twigs of the nerve from the modiolus close to the lamina spiralis ossea; *gs*, spiral gangliform enlargement of the nerve (habenaria ganglionaris); *fs*, nerve fibres running spirally along the gangliform swelling (Henle); 3, wide plexus; 4, close plexus of nerve fibres as in A.

recently been generally misconceived. The history of the discovery and subsequent appreciation of the nature of the canalis membranacea is fully given by Reichert. (Abhandl. d. Königl. Akad. d. Wissensch., Berlin, 1864.)

Cochlear division of the auditory nerve.—The nerve of the *cochlea* is shorter, flatter, and broader than any of the other nerves of the internal ear, and perforates the bone by a number of foramina at the bottom of the internal meatus, below the opening of the Fallopian aqueduct. These foramina are arranged in a shallow spiral groove (tractus spiralis foraminulentus) in the centre of the base of the cochlea; and they lead into small bony canals, which follow first the direction of the axis of the cochlea, through the modiolus, and then radiate outwards, between the plates of the bony lamina spiralis. In the centre of the spiral groove is a larger foramen, which leads to the canalis centralis modioli. Through the central foramen and straight canal the filaments for the last half-turn of the lamina spiralis are conducted; whilst the first two turns are supplied by filaments which occupy the smaller foramina and bent canals. In the bone the nerves have dark outlines, and near the edge of the spiral lamina they form a plexus which contains ganglion cells, and may be considered as a spiral ganglion contained in an osseous canal, *canalis spiralis modioli*, already mentioned. From the outer side of this ganglion the fibres, still possessing the dark outline, pass onwards with a plexiform arrangement, and, emerging from the bone beneath the labium tympanicum of the limbus, are collected into bundles, which, opposite a line of perforations situated at the junction with the membrana basilaris and named habenula perforata, present the appearance of conical extremities entering those perforations. Beyond this they have not yet been traced with certainty, although it seems probable, as suggested by Kölliker, that the nerves are in continuity with spindle-shaped cells in the organ of Corti.

Microscopic structure.—The *limbus laminæ spiralis* is a thick structure continuous with the periosteum of the vestibular surface of the osseous lamina. Its free surface is thrown into a number of fungiform elevations narrower at the base than at their extremities. Towards the inner part of the limbus these elevations are short and vertical, but those which are placed further out are more and more oblique and longer, and the labium vestibulare is formed by the outermost of them, which are lengthened into rib-like processes with flat extremities placed edge to edge, overhanging the sulcus spiralis like teeth. In the spaces between the elevations numerous small bodies like nuclei are disposed. In the floor of the sulcus spiralis where the labium tympanicum is continued into the membrana basilaris a series of elevations (apparent teeth of Corti) are directed into the membrane, and between their outer extremities are the oblique perforations occupied by the conical extremities of the nerve-bundles. This part is the *habenula perforata* of Kölliker: it is described by him along with the membrana basilaris, and by Henle along with the limbus. Henle considers the appearance of elevations as caused merely by the nerve-bundles grooving the under surface and leaving thicker structure between.

The *membrana basilaris* is divisible into an inner and an outer zone. The inner zone (habenula tecta vel arcuata) is covered over by the rods of Corti; the outer zone (zona pectinata) is attached peripherally to the walls of the canal through the medium of the cochlear ligament. The inner zone, together with the apparatus on its surface, continues, according to Henle, of a uniform breadth of about $\frac{1}{250}$th of an inch, both in the different parts of the same cochlea, and likewise in different animals: so that

Fig. 521.

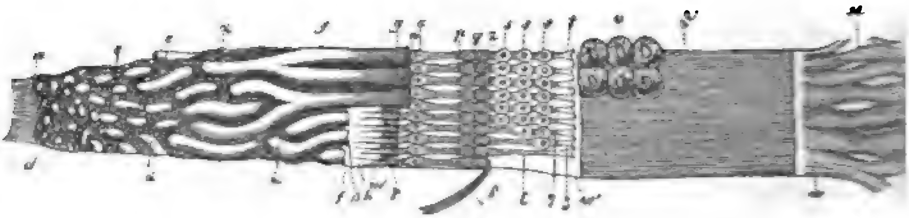


Fig. 521.—UPPER OR VESTIBULAR SURFACE OF A NARROW STRIP OF THE LAMINA SPIRALIS MEMBRANACEA (from Kölliker after Corti). $\frac{225}{1}$

The drawing is defective as regards the organ of Corti, but explains the nomenclature of the parts introduced by that author, and more or less adhered to by subsequent writers, although variously departed from in some of its details. The nomenclature adopted in the text has been selected from various writers, and it will be observed differs considerably from the following: *a*, periosteum of the zona spiralis ossea; *d w*, lamina spiralis membranacea; *d w'*, zona denticulata; *d f*, habenula sulcata; *d*, place where the periosteum thickens; *e*, granules in the areolæ of the habenula sulcata; *fg*, teeth of the first series; *gfh*, sulcus vel semicanalis spiralis; *h*, its lower wall; *hw'*, habenula denticulata; *hm*, apparent teeth; *nt*, teeth of the second series; *np*, inner segments of the same; *o*, swellings with nuclei; *pq* and *qz*, articulating pieces of the same; *t*, anterior segments of the second series; *s*, *s*, *s*, three cylindrical cells placed on them; *u*, epithelial cells placed under the membrane of Corti; *w'w*, zona pectinata; *aa*, band-like elevations of the habenula sulcata; β, placed where a tooth of the first series takes its origin; γ, holes between the apparent teeth; δ, fore part of one of the teeth of the second series thrown back; ϵ, one of them in its place without its epithelial cells; ζ one with only the lowest epithelial cell; η, one with the two lowest cells; ϑ, striæ or slight elevations of the zona pectinata; κ, periosteum attaching the lamina spiralis, with λ, apertures between the bundles.

the increasing breadth of the membrane from base to apex of the cochlea is due to broadening of the zona pectinata. According to the same observer the membrane is mainly homogeneous, and in the outer zone is thicker than in the inner, and somewhat tuberculated; but on the surface towards the membranous canal it is transversely striated by a layer of extremely delicate fibres; and on the other surface is a less perfect layer of fibres, with spindle-shaped corpuscles, which are placed longitudinally, and in young subjects are arranged so as to cover the inner zone and the attachment to the spiral ligament, leaving the outer zone free. A single layer of epithelium lies on this surface.

The *ligamentum spirale* (*musculus cochlearis* of Todd and Bowman) is triangular in section, receiving at its inner angle the basilar membrane, and spreading out rapidly to be attached by a broad base to the wall of the cochlea. Its fibres are directed outwards from the membrane to the bone, and it exhibits nuclei, like the ciliary muscle, whence Todd and Bowman conceived it to be muscular. Hensen represents it as composed of branching nucleated cells.

The organ of Corti.—Under this name may be comprised the whole of the structures intervening between the membrana basilaris and membrana tectoria. The most prominent part of it is formed by an outer and an inner series of rods, which, attached respectively to the inner and outer margins of the inner zone of the basilar membrane, meet together like the beams of a roof, and cover in a three-sided space, of which the inner zone of the basilar membrane is the floor. These structures, the *fibres* or *rods of Corti*, are closely adherent by their lower extremities to the basilar membrane. They are placed with the regularity of piano keys, and have been likened in con-

Fig. 522.

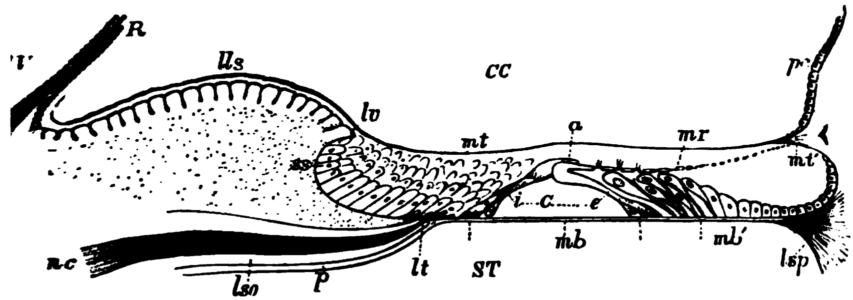


Fig. 522.—DIAGRAMMATIC OUTLINE OF A RADIAL SECTION THROUGH THE LAMINA SPIRALIS MEMBRANACEA, ORGAN OF CORTI, &c. (after Kölliker, Henle, and others). $\frac{250}{1}$

This figure may be regarded as a more enlarged and explanatory view of the part of fig. 518 representing the organ of Corti: SV, part of the scala vestibuli; CC, canalis cochleæ; ST, scala tympani; R, membrane of Reissner, forming the partition between the scala vestibuli and the canalis cochleæ; *lso*, a small part of the lamina spiralis ossea cut in the direction of one of the canals transmitting the cochlear nerves, *n c*; *p*, periosteum lining the scala tympani; *lls*, limbus laminæ spiralis, presenting a great thickening of the periosteum, in which over the extremity of the osseous spiral lamina is found the sulcus spiralis *ss*, and upon the upper surface of which are the toothed projections; *lv*, labium vestibulare; *lt*, labium tympanicum of the sulcus spiralis; *lv* to *lsp*, the lamina spiralis membranacea with its contained parts; *mt*, membrana tectoria passing from the limbus laminæ spiralis to the outer wall of the cochlear tube; *mb*, membrana basilaris, stretched from the labium tympanicum to the outer wall of the cochlear tube, where it expands in the ligamentum spirale, *lsp*; the part marked by the letters *mb*, between two short dotted lines, forms the zona tecta or z. arcuata; the part indicated by *m b'* and between the adjacent dotted lines is the zona pectinata; C, the organ of Corti; *i*, the internal rods; *e*, the external rods; these are set by their lower flattened ends on the basilar membrane, and are articulated together at their upper parts, *a*, the inner overlapping the outer; a nucleus is seen close to the base of each of the rods close on the basilar membrane; *mr*, membrana reticularis, stretched to the outer wall of the cochlea, *p c*; below *mr*, the cells of Corti lying obliquely on the outer rods, and between them the cells of Deiters, and between these and the outer wall of the cochlea epithelial cells; between *a* and *mr*, are indicated the perforations through which the hair-like terminations of the cells of Corti project: the sulcus spiralis is seen filled with cylindrical and other epithelium.

sistency to cartilage. The inner rods are more closely set and more numerous than the outer, and appear generally to be of a uniform breadth, flattened, and with a nucleiform body placed subjacent to the lower extremity. The outer rods are narrow and cylindrical in their shafts, and expanded at the lower extremity, which has a nucleiform body subjacent to it, as in the case of the inner rods. At their upper ends where they meet together, both sets of rods are thickened, and the parts which are in contact (*coins articulaires externes et internes* of Corti) have the appearance of quadrilateral plates directed outwards so that those of the inner row lie over those of the outer row, and those of the outer row are bent backwards from the direction in which the rods to which they belong are placed. From the junction line of the rods there extends outwards an extremely delicate network, the *lamina reticularis* of Kölliker (l. velamentosa, Deiters), which, it may be gathered from different accounts, is mainly constructed of a layer of squamous cells so disposed as to leave at least three rows of large perforations between them, and which are cemented together by a network of intervening substance which is sometimes detected when the cells are not. At its inner margin this lamina is united by flat plates to the inner

series of rods, and by narrow bodies with flattened extremities to the outer series: at its outer margin it has not yet been demonstrated that it is attached to the wall of the cochlea, although it has been supposed that its function might be to give fixity to the rods of Corti. Besides the rods and the lamina reticularis the organ of Corti presents various cellular elements. Of these the most important are an outer and inner series of cells with stiff

Fig. 523.

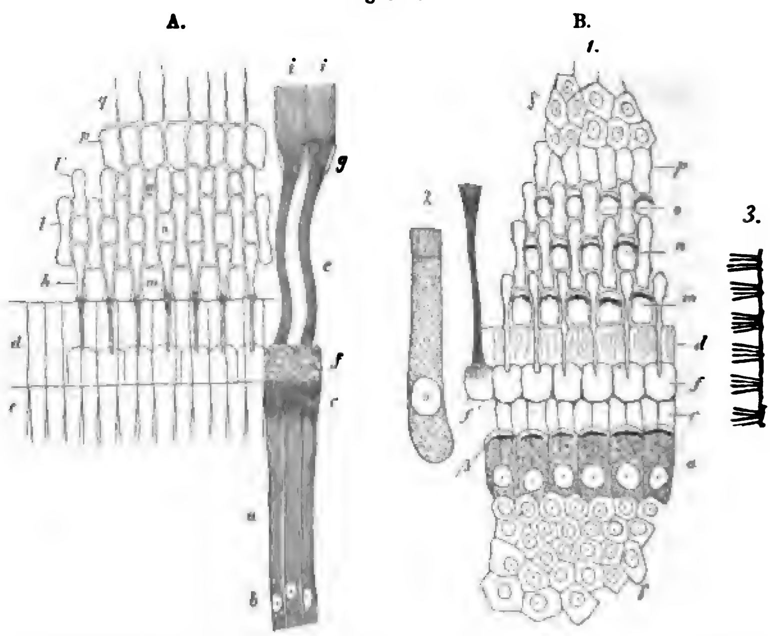


Fig. 523 A.—View from above of the Organ of Corti and Lamina Reticularis in the Ox (from Kölliker). $\frac{840}{1}$

a, inner rods or fibres of Corti; *b*, inner ends of the same with the deeper attached nuclei; *c*, articulating part of the same; *d*, clear plates appended, which with others from the outer rods form the commencement of the membrana reticularis; *e*, outer rods or fibres of Corti; *f*, their articulating portions; *g*, their terminations at the membrana basilaris; *h*, plates of the outer rods belonging to the membrana reticularis; *i i*, apparent extension of the ends of the fibres of Corti in the striæ of the zona pectinata of the basilar membrane; *l*, their inner connecting plates; *l'*, their outer connecting plates; *m*, *n*, *o*, first, second, and third series of perforations; *p*, rectangular terminal part of the lamina; *q*, prolongation of this in the form of fibres upon the large epithelial cells of the organ of Corti.

Fig. 523 B.—The Organ of Corti of the Cat (from Kölliker). $\frac{840}{1}$

1, the organ of Corti from above; *c*, the articulated part of the inner fibres or rods; *d*, connected plates which form the commencement of the membrana reticularis; *f*, articulating portions of the outer rods; *f'*, one of these connected with a filamentous process, and presenting granular or punctated contents; *m*, *n*, *o*, first, second, and third row of perforations, in which the cilia of Corti's cells are represented as dark arched lines; *a*, inner ciliated cells with (*β*) their cilia, forming the outermost part of the thick epithelium of the sulcus spiralis (*γ*), and which covers the inner fibres (rods) of Corti as far as their articulating parts; *δ*, outer part of the network of the lamina reticularis; 2, a cell of Corti with its hairs, but no visible filamentous appendage; 3, lateral view of the lamina reticularis with the bundles of cilia of the cells of Corti.

cilia projecting from their upper extremities. The *inner ciliated cells* form a single row resting on the articulating ends of the inner rods: the *outer ciliated cells* (pedunculated cells of Corti) are placed in three rows external to the outer rods, and are described as attached by pointed extremities to the membrana basilaris, and with their ciliated ends opposite the three rows of openings in the lamina reticularis; so that sometimes when the lamina is detached the ends of the cells are detached with it. Alternating with the outer ciliated cells are the *cells of Deiters*, which are fusiform and prolonged into a thread at each extremity, one passing up to the lamina reticularis, and the other down to the outer zone of the membrana basilaris. The upper surface of the remaining part of the basilar membrane is covered with hexagonal epithelium cells. The sulcus spiralis is likewise filled with large epithelial cells, which, according to Kölliker, project in a swelling distinct from the proper organ of Corti.

The mode of termination of the nerves, as has been already said, is uncertain, but minute fibres, consisting of axis-cylinders only, have been traced by Deiters into the organ of Corti, and his statements receive some support from Kölliker and Henle. These fibres are said to divide into a radiating set distributed both above and beneath the rods, and into a spiral set which are continued in the longitudinal direction of the canal.

The *membrana tectoria* is described by Henle as presenting three zones. The inner of these is delicate and presents large openings corresponding to elevations of the limbus; the middle or generally recognised part is formed of layers of fibres directed outwards, but yet crossing each other; and the outer part, unrecognised by most observers, is extremely delicate, forming a network, the openings in which are elongated in the direction of the canal.

The *membrane of Reissner* is an extremely easily torn membrane, on both sides of which epithelium has been described.

On the microscopic anatomy of the cochlea may be consulted Henle's Systematische Anatomie; Kölliker's Gewebelehre, 4th edition; also the papers of Corti, Claudius, Deiters, and Hensen, in Vols. III., VII., X., and XIII. of Siebold and Kölliker's Zeitsch. f. Wissensch. Zoologie; and Deiters, Untersuchungen über die Lamina Spiralis Membranacea.

BLOOD-VESSELS OF THE LABYRINTH.

Arteries.—The *internal auditory artery*, a branch from the basilar, enters the internal meatus of the ear with the auditory and facial nerves, and at the bottom of that shallow canal divides into vestibular and cochlear branches.

The *vestibular* branches are distributed to the common sinus, sacculus, and semicircular canals, with the branches of nerve which they accompany through the bony foramina. At first they ramify on the exterior of the membranous labyrinth, and end in capillaries both on the outer surface and in the substance of the special glassy layer. The plexus is best marked internally near the ending of the nerves.

The *cochlear* branches, twelve or fourteen in number, traverse the many small canals in the modiolus and bony lamina spiralis, and form in the latter a capillary plexus that joins at intervals the vas spirale, to be presently described. From this plexus offsets are distributed in the form of a fine network on the periosteum, but the vessels do not anastomose across the membrana basilaris. The *vas spirale* is a single, sometimes branched vessel which runs along the under surface of the membranous zone, near the bone: it is like a capillary in texture, but larger in size, and is pro-

bably venous. On the outer wall of the membranous canal there is a specially vascular strip which has received the name of *stria vascularis*.

Besides the foregoing vessel, which is the chief artery of the internal ear, the *stylo-mastoid* branch of the posterior auricular, and occasionally the occipital artery (Jones), send twigs to the vestibule and the posterior semicircular canal.

Veins.—The veins of the *cochlea* issue from the grooves of the cochlear axis and join the veins of the *vestibule* and semicircular canals: these accompany the arterial branches, and, uniting with those of the cochlea at the base of the modiolus, pour their contents into the superior petrosal sinus.

DEVELOPMENT OF THE EAR.

In the very young embryo the first rudiment of the ear is seen in the form of a small vesicle—the *primary auditory vesicle* lying at the side of the third primary cerebral vesicle. It has to a certain extent an appearance similar to that of the primary optic vesicle situated further forwards, and was long very naturally supposed to be formed like it by a protrusion of the wall of the primary medullary cavity of the brain; but it has latterly been established by various observers that it is produced solely by invagination of the integument, and has no original connection with the brain. During the third day of incubation it can be seen in the chick, still open to the outside, above and behind the second branchial lappet. It soon becomes completely closed, and is afterwards developed into the membranous labyrinth. The first complication which the vesicle exhibits is by the extension of a process upwards and backwards, which remains permanent in the lower vertebrata, but in mammals is obliterated, its vestiges remaining in the aqueduct of the vestibule. The semicircular canals next appear as elongated elevations of the surface of the primary vesicle: the middle portion of each elevation becomes separated from the rest of the

Fig. 524.

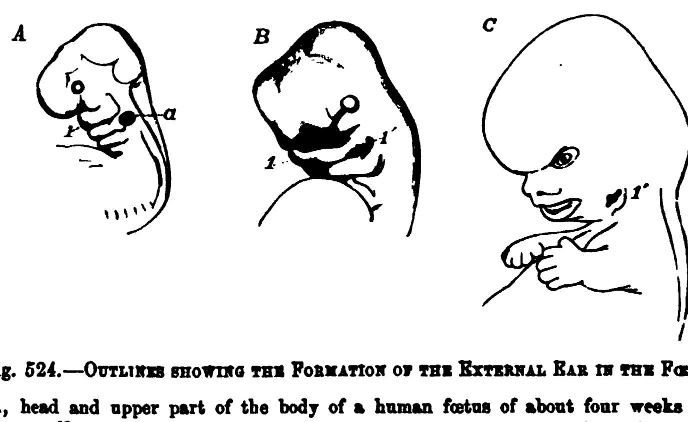


Fig. 524.—OUTLINES SHOWING THE FORMATION OF THE EXTERNAL EAR IN THE FŒTUS.

A, head and upper part of the body of a human fœtus of about four weeks (from nature). $\frac{10}{1}$ Four branchial plates (the first, forming the lower jaw, is marked 1), and four clefts are shown; the auditory vesicle (*a*), though closed, is visible from the transparency of the parts, and is placed behind the second branchial plate.

B, the same parts in a human fœtus of about six weeks (from Ecker). $\frac{7}{1}$ The third and fourth plates have nearly disappeared, and the third and fourth clefts are closed; the second is nearly closed; but the first (1') is somewhat widened posteriorly in connection with the formation of the meatus externus.

C, human fœtus of about nine weeks (from nature). $\frac{2}{1}$ The first branchial cleft is more dilated, and has altered its form along with the integument behind it in connection with the formation of the meatus externus and the auricle.

vesicle by bending in of its walls under it, and thus the elevation is converted into a tube open at each end, which subsequently becomes elongated and presents an ampullar dilatation. The cartilage which forms the osseous labyrinth is continuous with that of the rest of the primordial cranium. The cartilaginous walls of the cavity are united by connective tissue to the vesicle: this connective tissue, according to Kölliker, becomes divided into three layers, of which the outer forms the lining periosteum; the inner forms the external walls of the membranous labyrinth, while the intervening layer swells up into gelatinous tissue, the meshes of which become wider and wider, till at last the space is left which ultimately is found containing perilymph.

Fig. 525.

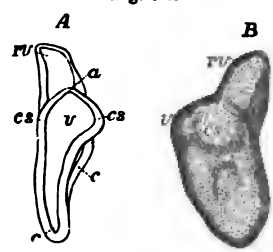


Fig. 525.—Labyrinth of the Human Fœtus of Four Weeks, magnified (from Kölliker).

A, from behind; B, from before; *v*, the vestibule; *r v*, recessus vestibuli, giving rise later to the aqueduct; *c s*, commencement of the semicircular canals; *a*, upper dilatation, belonging perhaps to another semicircular canal; *c*, cochlea.

The cochlea appears at first as a prolongation downwards from the auditory vesicle, but afterwards becomes tilted forwards. This prolongation of the auditory vesicle is the rudimentary canalis membranacea. Close to it is placed the cochlear nerve, with a gangliform extremity. The canal becomes elongated in a spiral direction, and the ganglion, which is elongated with it, becomes the ganglion spirale. Between the canal and the cartilaginous wall which afterwards surrounds it a large amount of connective tissue intervenes, and in this the cavities of the scala vestibuli and scala tympani appear at a later period, precisely as does the space for the perilymph in the vestibule. The modiolus and spiral lamina, according to Kölliker, are ossified without intervention of cartilage. Within the canalis membranacea Kölliker finds in the embryo a continuous epithelial lining, thin on the membrane of Reissner and on the outer wall, but forming a thick elevation in the position of the rods of Corti, and a larger elevation more internally, filling up the sulcus spiralis. On the surface of this latter elevation he observes a transparent body, the membrane of Corti.

Fig. 526.

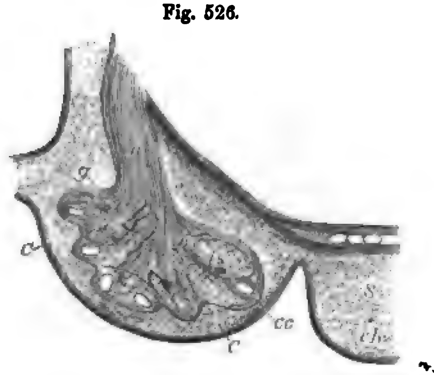


Fig. 526.—Transverse Section of the Cochlea in a Fœtal Calf, magnified (from Kölliker).

C, the wall of the cochlea, still cartilaginous; *c c*, canalis cochleæ; *l s*, placed in the tissue occupying the place of the scala vestibuli indicates the lamina spiralis; *n*, the central cochlear nerve; *g*, the place of the spiral ganglion; S, the body of the sphenoid; *c h*, chorda dorsalis.

With regard to the middle and external ear, it has been already explained at pages 65 and 66 that the external aperture, the tympanic cavity and the Eustachian tube are formed in the posterior or upper part of the first branchial cleft, which remains open except at the place where the passage is interrupted by the formation of the membrana tympani; and also that the incus and malleus are formed in the first branchial lappet from the proximal part of Meckel's cartilage, and the stapes and stapedius muscle and the styloid process in the second lappet. It is pointed out by

Kölliker that during the whole period of fœtal life the tympanic cavity is occupied by connective tissue, in which the ossicles are imbedded; and that only after the breathing process is commenced this tissue recedes before an expansion of the mucous membrane. The pinna is gradually developed on the posterior margin of the first branchial cleft. It is deserving of notice that congenital malformation of the external ear, with occlusion of the meatus and greater or less imperfection of the tympanic

Fig. 527.

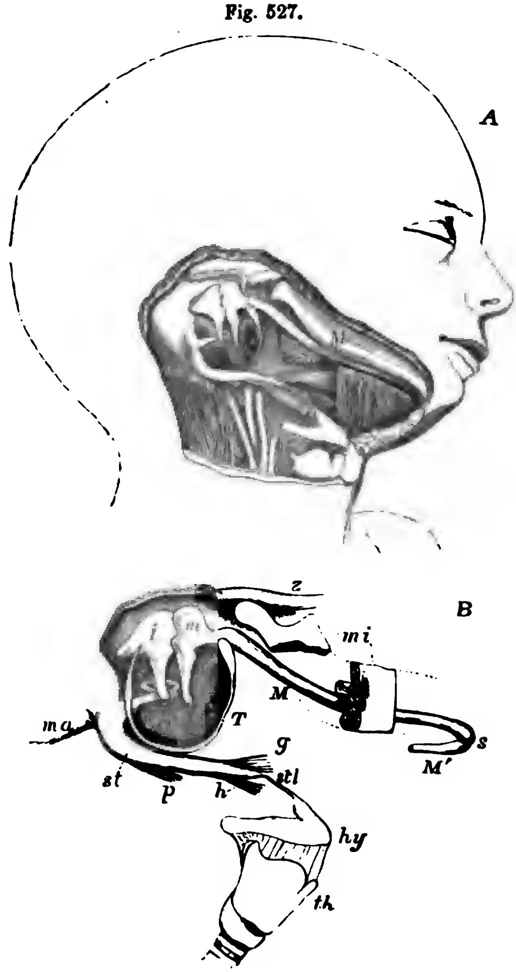


Fig. 527.—Views of the Cartilage of Meckel and parts connected with the First and Second Branchial Plates.

A. (after Kölliker), head of a fœtus of about eighteen weeks, showing the cartilage of Meckel in connection with the malleus, &c. M, the cartilage of Meckel of the right side.

B (from nature). An enlarged sketch explanatory of the above view; z, the zygomatic arch; ma, the mastoid process; mi, portions of the lower jaw of which the parts near the angle and the symphysis have been removed; M, the cartilage of Meckel of the right side; M′, a small part of that of the left side, joining the left cartilage at s, the symphysis; T, the tympanic ring; m, the malleus; i, the incus; s, the stapes; sta, the stapedius muscle; st, the styloid process; p, h, g, the stylo-pharyngeus, stylo-hyoid and stylo-glossus muscles, stl, stylo-hyoid ligament attached to the lesser cornu of the hyoid bone; hy, the hyoid bone; th, thyroid cartilage. In A, the head being turned somewhat upwards, the same parts are shown, together with the surrounding muscles, the carotid artery, jugular vein, &c.

apparatus, are observed in connection with abnormal development of the deeper parts of the first and second branchial lappets and the intermediate cleft; while cases have been observed of the persistence in the neck of the adult of one or more of the branchial clefts situated behind the first. (Allen Thomson, Proceed. Roy. Soc. of Edin. 1844, and Edin. Journ. of Med. Sc. 1847.)

THE NOSE.

The nose is the special organ of the sense of smell. It has also other functions to fulfil;—for, communicating freely with the cavities of the mouth and lungs, it is concerned in respiration, voice, and taste; and by means of muscles on its exterior, which are closely connected with the muscles of the face, it assists in the expression of the different passions and feelings of the mind.

Fig. 528.

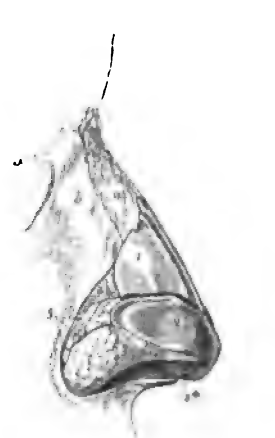


Fig. 528.—Lateral View of the Cartilages of the Nose (from Arnold). ¾

a, right nasal bone; *b*, nasal process of the superior maxillary bone; 1, upper lateral cartilage or wing-like expansion of the septal cartilage; 2, lower lateral cartilage (outer part); 2*, inner part of the same; 3, sesamoid cartilages.

This organ consists of, first, the anterior prominent part, composed of bone and cartilages, with muscles already described, which slightly move the cartilages, and two orifices, *anterior nares*, opening downwards; and, secondly, of the two nasal fossæ, in which the olfactory nerves are expanded. The nasal fossæ are separated from each other by a partition, *septum nasi*, formed of bone and cartilage: they communicate at the outer side with hollows in the neighbouring bones (ethmoid, sphenoid, frontal, and superior maxillary); and they open backwards into the pharynx through the posterior nares. The skin of the nose is studded, particularly in the grooves of the alæ or outer walls of the nostrils, with numerous small openings, which lead to sebaceous follicles. Within the margin of the nostrils there is a number of short, stiff, and slightly curved hairs—*vibrissæ*, which grow from the inner surface of the alæ and septum nasi, as far as the place where the skin is continuous with the mucous membrane lining the cavity of the nose.

CARTILAGES OF THE NOSE.

These are the chief support of the outer part of the organ. They occupy the triangular opening seen in front of the nasal cavity in the dried skull, and assist in forming the septum between the nasal fossæ. There are usually reckoned two larger and three smaller cartilages on each side, and one central piece or cartilage of the septum.

The *upper lateral cartilages* (cartilagines laterales nasi) are situated in the upper part of the projecting portion of the nose, immediately below the free margin of the nasal bones. Each cartilage is flattened and triangular in shape, and presents one surface outwards, and the other inwards towards

the nasal cavity. The anterior margin, thicker than the posterior one, meets the lateral cartilage of the opposite side above, but is closely united with the edge of the cartilage of the septum below; so closely indeed, that by some, as Henle, the upper lateral are regarded as reflected wings of the median cartilage. The inferior margin is connected by fibrous membrane with the lower lateral cartilage; and the posterior edge is inserted into the ascending process of the upper maxilla and the free margin of the nasal bone.

Fig. 529.

Fig. 530.

Fig. 529.—Front View of the Cartilages of the Nose (from Arnold). $\frac{3}{4}$

a, *a′*, nasal bones; 1, 1′, upper lateral cartilages or wing-like expansions of the septal cartilage; 2, 2′, lower lateral cartilages.

Fig. 530.—View of the Cartilages of the Nose from below (from Arnold). $\frac{3}{4}$

2, 2′, outer part of the lower lateral cartilages; 2*, 2*, inner part of the same; 4, lower edge of the cartilage of the septum.

The *lower lateral cartilages* (cartilagines alarum nasi) are thinner than the preceding, below which they are placed, and are chiefly characterised by their peculiar curved form. Each cartilage consists of an elongated plate, so bent upon itself as to pass in front and on each side of the nostril to which it belongs, and by this arrangement serves to keep it open. The outer portion is somewhat oval and flattened, or irregularly convex externally. Behind, it is attached to the margin of the ascending process of the upper maxilla, by tough fibrous membrane, in which are two or three cartilaginous nodules (cartilag. minores vel sesamoideæ); above, it is fixed, also by fibrous membrane, to the upper lateral cartilage, and to the lower and fore part of the cartilage of the septum. Towards the middle line it is curved backwards, bounding a deep mesial groove, at the bottom of which it meets with its fellow of the opposite side, and continues to pass backwards, forming a small part of the columna nasi, below the level of the cartilage of the septum. This inner part of the cartilage of the ala is thick and narrow, curls outwards, and ends in a free rounded margin which projects outwards towards the nostril. The lower and most prominent portion of the ala of the nose, like the lobule of the ear, is formed of thickened skin with subjacent tissue, and is unsupported by cartilage.

The *cartilage of the septum* has a somewhat triangular outline, and is thicker at the edges than near the centre. It is placed nearly vertically in the middle line of the nose, and completes, at the fore part, the separation between the nasal fossæ. The anterior margin of the cartilage, thickest above, is firmly attached to the back of the nasal bones near their line of junction; and below this it lies successively between the upper and the lower lateral cartilages, united firmly with the former and loosely with the latter. The posterior margin is fixed to the lower and fore part of the central plate of the ethmoid bone; and the lower margin is received into

the groove of the vomer, as well as into the median ridge between the superior maxillæ.

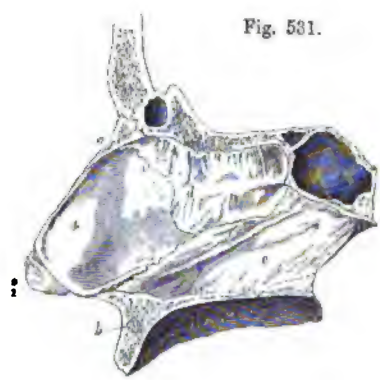


Fig. 531.—Osseous and Cartilaginous Septum of the Nose, seen from the Left Side (from Arnold). ⅔

a, right nasal bone; *b*, superior maxillary bone; *c*, sphenoidal sinus; *d*, perpendicular plate of the ethmoid bone; *e*, vomer; 2*, inner part of the right lower lateral cartilage; 4, cartilage of the septum.

This cartilage is the persistent anterior extremity of the primordial cranium. In young subjects it is prolonged back to the body of the pre-sphenoid bone; and in many adults an irregular thin band remains between the vomer and the central plate of the ethmoid.

NASAL FOSSÆ.

The nasal fossæ, and the various openings into them, with the posterior nares, have been previously described as they exist in the skeleton, and the

Fig. 532.

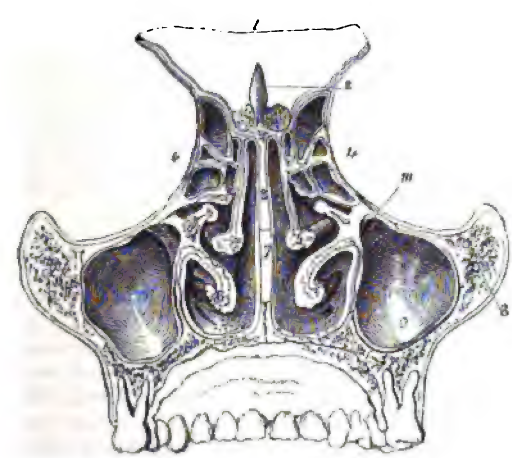


Fig. 532.—Transverse Vertical Section of the Nasal Fossæ seen from behind (from Arnold). ¾

1, part of the frontal bone; 2, crista galli; 3, perpendicular plate of the ethmoid; between 4 and 4, the ethmoid cells; 5, right middle spongy bone; 6, left lower spongy bone; 7, vomer; 8, malar bone; 9, maxillary sinus; 10, its opening into the middle meatus.

greater part of that description is also applicable generally to the nose in a recent state; but it is proper to mention certain differences in the form and

dimension of parts, which depend on the arrangement of the lining membrane, viz.—

Throughout the whole of the nasal fossæ it is to be observed that—

First, owing to the thickness of the membrane in question, (which not only lines the walls of the fossæ, but covers the spongy bones on both sides,) the nasal cavity is much narrower in the recent state. Second, in consequence of the prolongations of membrane on their free margins, the turbinate bones, and more particularly the lower pair, appear in the recent state to be both more prominent, and longer in the direction from before backwards, than in the dried skull. Third, by the arrangement of the mucous membrane round and over the orifices which open into the nasal fossæ, some of the foramina in the bones are narrowed, and others completely closed.

In the individual parts of the nasal fossæ the following particulars are to be noticed:—

In the *upper meatus*, the small orifice which leads into the posterior ethmoidal cells is lined by a prolongation of the thin mucous membrane which continues into those cavities; but the spheno-palatine foramen is covered over by the Schneiderian membrane, so that no such opening exists in the recent nasal fossa.

In the *middle meatus* the aperture of the infundibulum is nearly hidden by an overhanging fold of membrane; it leads directly into the anterior ethmoidal cells, and through them into the frontal sinus. Below and behind this, the passage into the antrum of Highmore is surrounded by a circular fold of the pituitary membrane, (sometimes prominent and even slightly valvular,) which leaves a circular aperture much smaller than the foramen in the bony meatus.

In the *lower meatus*, the inferior orifice of the nasal duct is defended by one or two folds of membrane; and when there are two, the folds are often adapted so accurately together as to prevent even air passing back from the cavity of the nose to the lachrymal sac.

In the *roof* the apertures in the cribriform plate of the ethmoid bone are closed by the membrane, but the openings into the sphenoidal sinuses receive a prolongation from it.

In the *floor* the incisor foramen is in the recent state generally closed. Sometimes, however, a narrow funnel-shaped tube of the mucous membrane descends for a short distance into the canal, but is closed before it reaches the roof of the palate. Vesalius, Stenson and Santorini believed that this tube of membrane opened generally into the roof of the mouth by a small aperture close behind the interval between the central incisor teeth. Haller, Scarpa, and, more recently, Jacobson, find that in man it is usually closed, and often difficult of detection. (See Cuvier's Report on a paper by Jacobson, "Annales du Museum d'Hist. Naturelle;" Paris, 1811; vol. xviii. p. 412.)

MUCOUS MEMBRANE.

The pituitary or Schneiderian membrane, which lines the cavities of the nose, is a highly vascular mucous membrane, inseparably united, like that investing the cavity of the tympanum, with the periosteum and perichondrium over which it lies. It is continuous with the skin through the nostrils; with the mucous membrane of the pharynx through the posterior apertures of the nasal fossæ; with the conjunctiva through the nasal duct and lachrymal canaliculi; and with the lining membrane of the several sinuses which communicate with the nasal fossæ. The pituitary membrane, however, varies much in thickness, vascularity, and general appearance in these different parts. It is thickest and most vascular over the turbinate bones (particularly the inferior), from the most dependent parts of which it forms projections in front and behind, thereby increasing the surface to some extent. On the septum nasi the pituitary membrane is still very thick and spongy; but in the intervals between the turbinate bones, and over the floor of the nasal fossæ, it is considerably thinner. In the maxillary, frontal,

and sphenoidal sinuses, and in the ethmoidal cells, the mucous lining membrane, being very thin and pale, contrasts strongly with that which occupies the nasal fossæ.

Fig. 533.

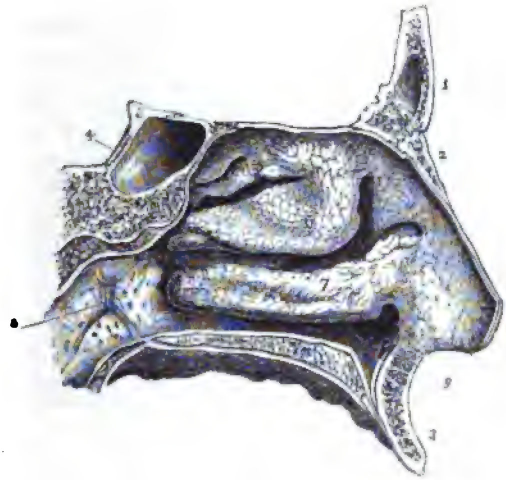


Fig. 533.—Outer Wall of the Left Nasal Fossa, covered by the Pituitary Membrane (from Arnold). $\frac{1}{2}$

1, frontal bone; 2, left nasal bone; 3, superior maxillary; 4, body of the sphenoid with the sphenoidal sinus; 5, projection of the membrane covering the upper spongy bone; 6, that of the middle; 7, that of the lower; the upper, middle, and lower meatuses are seen below the corresponding spongy bones; 8, opening of the Eustachian tube; 9, depression of the lining membrane of the nose in the anterior palatine canal.

In respect of the characters of the mucous membrane, three regions ot the nasal fossæ may be distinguished. Thus, the region of the nostrils, including all the part which is roofed by the nasal cartilages, is lined with stratified squamous epithelium; the remainder of the fossæ is divisible into two parts, viz., the olfactory region in which the epithelium is nonciliated and columnar, and the respiratory region in which it is ciliated and columnar. The membrane in the respiratory part, consisting of the inferior turbinated and all the lower portions of the fossæ, is studded with numerous mucous glands, which are of branched aciuated appearance, and open by apparent orifices on the surface. These are most numerous about the middle and hinder parts of the nasal fossæ, and are largest at the back of the septum near the floor of the nasal cavity. They are much smaller and

Fig. 534.

Fig. 534.—Vertical Section of a small portion of the Membrane of the Nose from the Olfactory Region (from Ecker). $\frac{50}{1}$

a, coloured part of the epithelium; *a'*, nuclei; *b*, deeper part containing the olfactory cells and filaments; *c*, connective tissue of the mucous membrane; *d*, one of the mucous glands; *d'*, its duct; *e*, twig of the olfactory nerve; *e'*, small twig passing to the surface.

less numerous in the membrane lining the several cavities which communicate with the nasal fossæ.

The olfactory region or that in which the olfactory nerve is distributed, includes the upper and middle turbinated parts, and the upper portion of the septum. Its mucous membrane is thicker and more delicate in consistence than that of the ciliated region, being soft and pulpy. The columnar cells on its surface are prolonged at their deep extremities into threads which have been observed to communicate with stellate cells of the connective tissue. Beneath the columnar cells is a considerable thickness of densely nucleated tissue, compared by Henle to the cortical brain substance. The glands of this region are numerous; but are of a more simple structure than those in the lower part of the fossæ.

Fig. 535.

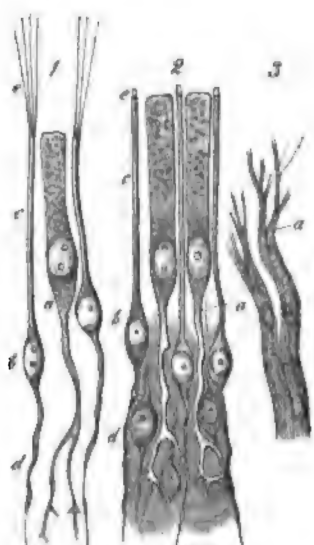


Fig. 535.—Cells and Terminal Nerve-fibres of the Olfactory Region (from Frey after Schultze).

1, from the frog; 2, from man; *a*, epithelial cell, extending deeply into a ramified process; *b*, olfactory cells; *c*, their peripheral rods; *e*, their extremities, seen in 1 to be prolonged into ciliary hairs; *d*, their central filaments; 3, olfactory nerve-fibres from the dog; *a*, the division into fine fibrillæ.

Olfactory Cells.—Intermixed with the columnar epithelial cells of the olfactory region, and so numerous as to surround each of them, are certain peculiar bodies, each consisting of a spindle-shaped nucleated cell, from which proceed a superficial and a deep process. The superficial process is a cylindrical or slightly tapering thread passing directly to the surface, and terminating abruptly at the same level as the epithelial cells between which it lies: the deep process is more slender, and passes vertically inwards. Both processes frequently present a beaded appearance similar to that observed in fine nerve-filaments, and considered to be of a similar accidental origin. It was suggested by Max Schultze, the discoverer of the olfactory cells, and is highly probable, that the deep processes are directly continuous with the filaments of the olfactory nerve, but the continuity does not appear to have been actually observed.

The superficial process of the olfactory cell was observed by Schultze to be surmounted by a short stiff hair-like process, and has been so described by others; but both the discoverer and others are now agreed that this appearance results from the coagulation of albumen escaped from the interior of the process. Long and fine hair-like processes do, however, exist on the olfactory membranes of amphibia, reptiles, and birds, and had been previously pointed out by Schultze.

Olfactory Nerve.—The filaments of this nerve, lodged at first in grooves on the surface of the bone, enter obliquely the substance of the Schneiderian membrane, and pass to their distribution between its mucous and fibrous layers. The nerves of the septum are rather larger than those of the outer wall of the nasal fossæ; they extend over the upper third of the septum,

and as they descend become very indistinct. The nerves of the outer wall are divided into two groups—the posterior branches being distributed over the surface of the upper spongy bone, and the anterior branches descending over the plane surface of the ethmoid and the middle spongy bone.

Fig. 536.

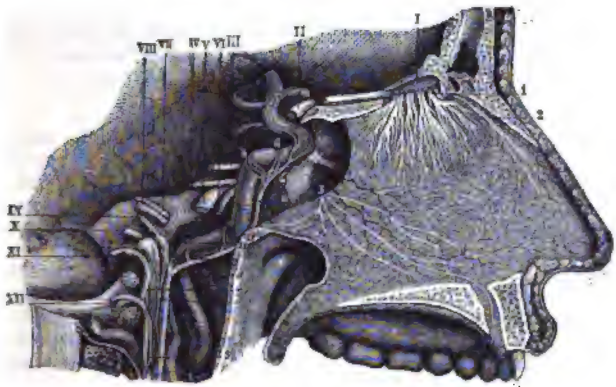


Fig. 536.—Nerves of the Septum Nasi, seen from the right side (from Sappey after Hirschfeld and Leveillé). ⅜

I, the olfactory bulb; 1, the olfactory nerves passing through the foramina of the cribriform plate, and descending to be distributed on the septum; 2, the internal or septal twig of the nasal branch of the ophthalmic nerve; 3, naso-palatine nerves.

The olfactory nerves as they descend ramify and unite in a plexiform manner, and the filaments join in brush-like and flattened tufts, which, spreading out laterally and communicating freely with similar offsets on each side, form a fine net-work, with elongated and narrow intervals between the points of junction; but it is impossible to trace by dissection the termination of the nerves in the membrane, in consequence of the difficulty of recognising the filaments, destitute of dark outline, as they lie among the other nucleated tissues.

Fig. 537.

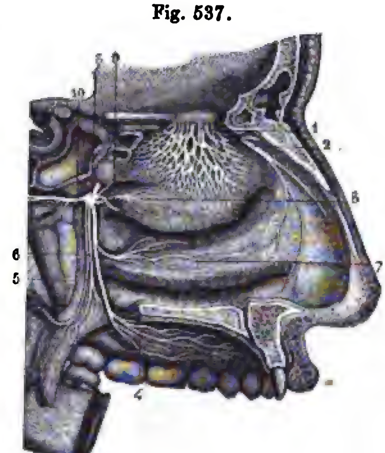


Fig. 537.—Nerves of the Outer Wall of the Nasal Fossæ (from Sappey after Hirschfeld and Leveillé). ⅜

1, network of the branches of the olfactory nerve, descending upon the region of the superior and middle turbinated bones; 2, external twig of the ethmoidal branch of the nasal nerve; 3, spheno-palatine ganglion; 4, ramification of the anterior palatine nerves; 5, posterior, and 6, middle divisions of the palatine nerves; 7, branch to the region of the inferior turbinated bone; 8, branch to the region of the superior and middle turbinated bones; 9, naso-palatine branch to the septum cut short.

In their nature the olfactory filaments differ much from the fibres of the cerebral and spinal nerves: they contain no white substance of Schwann,

are pale, and finely granular in texture, firmly adherent one to another, and have oval corpuscles on their surface.

The greater part of the mucous membrane of the nasal fossæ is provided with nerves of common sensibility, derived from branches of the fifth pair: these have already been described at pp. 599, 603 and 604.

Blood-vessels.—The arteries and veins of the nose are derived from numerous sources: those of the interior form rich plexuses of capillaries in the lining membrane. The description of the arteries will be found at pp. 350, 356, 361 and 362; that of the veins at pp. 456 and 464.

DEVELOPMENT OF THE NOSE.

The organ of smell, as was first pointed out by V. Baer, owes its origin, like the primary auditory vesicle and the crystalline lens of the eye, to a depression of the integument. This depression, the primary olfactory groove, is at first encircled by a uniform wall, and is unconnected with the mouth. This stage has been observed by Kölliker in the human embryo of four weeks. Soon, however, by the unequal growth of the surrounding parts, a groove is formed, descending from the pit and passing into the mouth. Thus the middle frontal process is isolated between the grooves of opposite sides, while the lateral frontal process separates the nostril from the eye (p. 65). The maxillary lobes, growing forwards from behind the eyes, complete the boundaries of the nostrils, which then open into the fore part of the mouth. Kölliker observes this stage in the latter half of the second month. The palate subsequently grows inwards to the middle line, as has been elsewhere stated, and separates the nasal from the buccal cavity; leaving only the extremely minute communication of the incisor foramen. Meanwhile, with the growth of the face, the nasal fossæ deepen, and the turbinated bones make their appearance as processes from their walls. Observations are still wanting to determine whether the olfactory nerves are developed from the bulbs, and have thus a cerebral origin, or are separately formed from peripheral blastema like all other nerves, with the exception of the optic.

Fig. 537.*

A B C

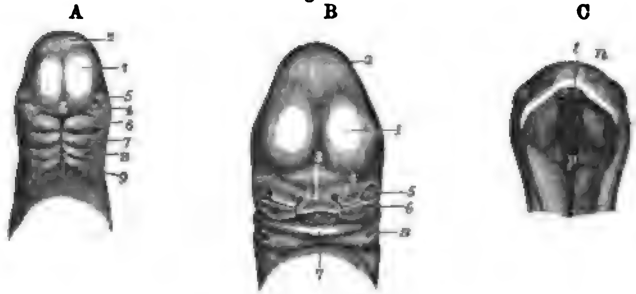


Fig. 537.*—VIEWS OF THE HEAD OF HUMAN EMBRYOES, ILLUSTRATING THE DEVELOPMENT OF THE NOSE.

A, Head of an embryo of three weeks (from Ecker). $\frac{10}{1}$ 1, anterior cerebral vesicle; 2, middle vesicle; 3, nasal or middle frontal process; 4, superior maxillary process; 5, eye; 6, inferior maxillary process or first visceral plate, and below it the first cleft; 7, 8, and 9, second, third, and fourth plates and clefts.

B, Head of an embryo of about five weeks (from Ecker). $\frac{10}{1}$

1, 2, 3, and 5, the same parts as in A; 4, the external nasal or lateral frontal process, inside which is the nasal groove; 6, the superior maxillary process; 7, the inferior maxilla; ×, the tongue seen within the mouth; 8, the first branchial cleft which becomes the outer part of the meatus auditorius externus.

C, View of the head of an embryo of eight weeks seen from below, the lower jaw having been removed (from Kölliker). $\frac{4}{1}$

n, the external nasal apertures; *i*, intermaxillary or incisor process, and to the outer side of this the internal nasal aperture; *m*, one of the palatal processes of the upper jaw, which advancing inwards from the sides form the partition between the mouth and nose; *p*, common cavity of the nose, mouth, and pharynx.

Section VI.—SPLANCHNOLOGY.

Under the division Splanchnology will be described those organs of the body which have not found a place in any of the foregoing parts of the work. These consist of the organs of digestion, the organs of respiration, the urinary organs, and the organs of generation.

ORGANS OF DIGESTION.

The *digestive apparatus* includes that portion of the organs of assimilation within which the food is received and partially converted into chyle, and from which, after the chyle has been absorbed, the residue or excrement is expelled. It consists mainly of a tubular part,—the *alimentary canal*, together with various glands of which it receives the secretions.

The alimentary canal is a long membranous tube commencing at the mouth and terminating at the anus, composed of certain tunics or coats, and lined by a continuous mucous membrane from one end to the other. Its average length is about thirty feet, being about five or six times the length of the body. Its upper extremity is placed beneath the base of the skull, the succeeding portion traverses the thorax, and by far the greater part is contained within the cavities of the abdomen and pelvis.

The part situated above the diaphragm consists of the organs of mastication, insalivation and deglutition, and comprises the *mouth*, with the teeth and salivary glands, the *pharynx*, and the *œsophagus* or gullet. The remainder includes that part of the canal which is more immediately engaged in the digestive process, in absorption and in defecation, as the stomach and the small and large intestine. The glands which are most intimately connected with digestion consist of those very numerous smaller glandular organs which are situated in the mucous membrane of the alimentary canal, and the larger glands, such as the pancreas and liver, whose ducts open within the canal.

THE MOUTH.

The *mouth*, or, more definitely, the *buccal cavity*, is the space included between the lips and the throat. Bounded by the lips, cheeks, tongue, and the hard and soft palate, it communicates behind with the pharynx through an opening called the *fauces* (isthmus faucium). The cavity of the mouth is lined throughout by a mucous membrane, which is of a pink rosy hue during life, but pale grey after death, and which presents peculiarities of surface and structure to be noticed hereafter.

The *lips* and *cheeks* are composed of an external layer of skin, and of an internal layer of mucous membrane, together with muscles, vessels, and nerves already fully described in other parts of this work, some areolar tissue, fat, and numerous small glands. The free border of the lips is protected by a dry mucous membrane, which becomes continuous with the skin, is covered with numerous minute papillæ, and is highly sensitive. On the inner surface of each lip, the mucous membrane forms a fold in the middle line, connecting the lip with the gums of the corresponding jaw. These are the *fræna* or *frænula* of the lips: that of the upper lip is much the larger.

Numerous small glands, called *labial glands*, are found beneath the

mucous membrane of the lips, around the opening of the mouth. They are situated between the mucous membrane and the orbicularis oris muscle. They are compound glands of a rounded form, the largest of them not exceeding the size of a split pea; and they open into the mouth by distinct orifices.

Between the buccinator muscle and the mucous membrane of the cheek, by which it is lined in its whole extent, are the *buccal* glands, similar to the labial glands, but smaller. Two or three glands, larger than the rest, found between the masseter and buccinator muscles, and opening by separate ducts near the last molar tooth, are called the *molar* glands. The duct of the parotid gland also opens upon the inner surface of the cheek, opposite to the second upper molar tooth.

Immediately within the lips and cheek, are the *dental arches*, consisting of the teeth, gums, and maxillæ. The jaw-bones, the articulation and movements of the lower maxilla, and the muscles used in mastication, are elsewhere described. The *gums* (gingivæ) are composed of a dense fibrous tissue, connected very closely with the periosteum of the alveolar processes, and covered by a red and highly vascular but not very sensitive mucous membrane, which is smooth in its general surface, but is beset with fine papillæ in the immediate vicinity of the teeth.

THE TEETH.

In the human subject, as in mammalia generally, two sets of teeth make their appearance in the course of life, of which the first constitutes the *temporary*, *deciduous*, or *milk* teeth, whilst the second is named the *permanent* set. The temporary teeth are twenty in number, ten in each jaw, and the permanent set consists of thirty-two, sixteen above and sixteen below.

Deficiencies in the number of the teeth sometimes occur, and the number is frequently increased by one or more supernumerary teeth. These are usually small, and provided with only a single fang; and, though generally distinct, they are sometimes attached to other teeth: they occur more frequently near the front than the hinder teeth, and are more often met with in the upper than in the lower jaw.

General Characters of the Teeth.—Every tooth consists of three portions, viz., one which projects above the gums and is named the body or *crown*,—another which is lodged in the alveolus or socket, and constitutes the root or *fang*,—and a third, intermediate between the other two, and, from being more or less constricted, named the cervix or *neck*. The size and form of each of these parts vary in the different kinds of teeth.

The roots of all the teeth are accurately fitted to the alveoli of the jaws, in which they are implanted. Each alveolus is lined by the periosteum, which also invests the contained fang as high as the cervix. This dental periosteum, sometimes named the periodontal membrane, is blended with the dense and slightly sensitive tissue of the gums, which closely surrounds the neck of the tooth. The roots of all the teeth taper from the cervix to the point, and this form, together with the accurate adjustment to the alveolus, has the effect of distributing the pressure during use over the whole socket, and of preventing its undue action on the apex of the fang through which the blood-vessels and nerves enter.

The thirty-two permanent teeth consist of four incisors, two canines, four bicuspids, and six molars in each jaw. The twenty temporary teeth are four incisors, two canines, and four molars above and below. There are

no bicuspids among the temporary teeth, but the eight deciduous molars are succeeded by the eight bicuspids of the permanent set. The relative position and arrangement of the different kinds of teeth in the jaws may be expressed by the following formula, which also exhibits the relation between the two sets in these respects :—

		MO.	BI.	CA.	IN.	CA.	BI.	MO.		
Temporary teeth . .	Upper		2	1	4	1	2		=10	=20
	Lower		2	1	4	1	2		=10	
Permanent teeth . .	Upper	3	2	1	4	1	2	3	=16	=32
	Lower	3	2	1	4	1	2	3	=16	

Special Characters of the Permanent Teeth.—The *incisors*, eight in number, are the four front teeth in each jaw, and are so named from being adapted for cutting or dividing the soft substances used as food. Their *crowns* are chisel-shaped, and have a sharp horizontal cutting edge, which by continued use is bevelled off behind in the upper teeth, but in the lower teeth is worn down in front, where it comes in contact with the overlapping edges of the upper teeth. Before being subjected to wear, the horizontal edge of each incisor tooth is serrated or marked by three small prominent points. The

Fig. 538.

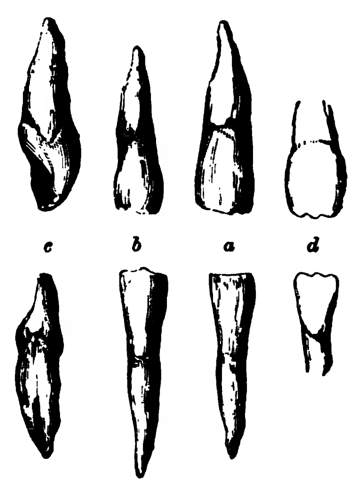


Fig. 538.—Incisor Teeth of the Upper and Lower Jaws.

a, front view of the upper and lower middle incisors ; *b*, front view of the upper and lower lateral incisors ; *c*, lateral view of the upper and lower middle incisors, showing the chisel shape of the crown ; a groove is seen marking slightly the fang of the lower tooth ; *d*, the upper and lower middle incisor teeth before they have been worn, showing the three pointed projections of the cutting edge.

anterior surface of the crown is slightly convex, and the posterior concave. The *fang* is long, single, conical, and compressed at the sides, where it sometimes though rarely presents a slight longitudinal furrow.

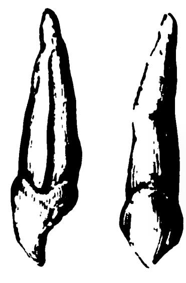
The lower incisor teeth are placed vertically in the jaw, but the corresponding upper teeth are directed obliquely forwards. The upper incisors are, on the whole, larger than the lower ones.

In the upper jaw the central incisors are larger than the lateral; the reverse is the case in the lower jaw, the central incisors being there the smaller, and being, moreover, the smallest of all the incisor teeth.

The *canine* teeth (cuspidati), four in number, are placed one on each side, above and below, next to the lateral incisors. They are larger and stronger than the incisor teeth. The *crown* is thick and conical, convex in front and hollowed behind, and may be compared to that of a large incisor

tooth the angles of which have been removed, so as to leave a single central point or *cusp*, whence the name *cuspidate* applied to these teeth.

Fig. 539.



b a

Fig. 539.—Canine Tooth of the Upper Jaw.

a, front view; *b*, lateral view, showing the long fang grooved on the side.

The point always becomes worn down by use. The *fang* of the canine teeth is single, conical, and compressed at the sides: it is longer than the fangs of any of the other teeth, and is so thick as to cause a corresponding prominence of the alveolar arch: on the sides it is marked by a groove, an indication, as it were, of the cleft or division which appears in the teeth next following.

The upper canines, popularly called the *eye-teeth*, are larger than the lower, and in consequence of this, as well as of the greater width of the upper range of incisors, they are thrown a little farther outwards than the lower canine teeth. In the dog-

Fig. 540.

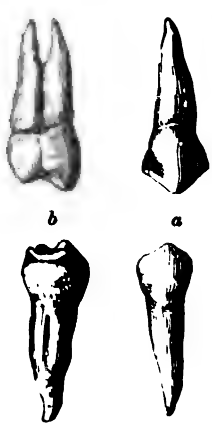


Fig. 541.

Fig. 540.—First Bicuspid Tooth of the Upper and Lower Jaws.

a, front view; *b*, lateral view, showing the lateral groove of the fang, and the tendency in the upper to division.

Fig. 541.—First Molar Tooth of the Upper and Lower Jaws.

They are viewed from the outer aspect.

tribe, and in the carnivora generally, these teeth acquire a great size, and are fitted for seizing and killing prey, and for gnawing and tearing it when used as food.

The *bicuspids* (bicuspidati), also called premolars, are four in each jaw; they are shorter and smaller than the canines, next to which they are placed, two on each side. The *crown* is compressed before and behind, its greater diameter being across the jaw. It is convex, not only on its outer or labial surface, like the preceding teeth, but on its inner surface also, which rises vertically from the gum: its free extremity is broader than that of an incisor or canine tooth, and is surmounted by two pointed tubercles or cusps, of which the external one is larger and higher than the other. The *fang* is also flattened, and is deeply grooved in all cases, showing a tendency to become double. The apex of the fang is generally bifid, and in the first upper bicuspid the root is often cleft for a considerable distance; but the bicuspid teeth are very variable in this respect, and may be, all four, free from any trace of bifidity of the root. The upper bicuspids are larger than the lower ones, and their cups are more deeply divided. Sometimes the first lower bicuspid has only

one tubercle distinctly marked, *i.e.*, the external, and in that case approaches in figure to a canine tooth.

The *molar* teeth, true or large molars, or multicuspid teeth, are twelve in number, and are arranged behind the bicuspid teeth, three on each side, above and below. They are distinguished by the large size of the crown, and by the great width of its grinding surface. The first molar is the largest, and the third is the smallest, in each range, so as to produce a gradation of size in these teeth. The last molar in each range, owing to its late appearance through the gums, is called the *wisdom-tooth*, dens sapientiæ. The *crowns* of the molar teeth are low and cuboid in their general form. Their outer and inner surfaces are convex, but the crowns are rather flattened before and behind. The grinding surface is nearly square in the lower teeth, and rhomboidal in the upper, the corners being rounded off: it is not smooth, but is provided with four or five trihedral tubercles or cusps (whence the name of multicuspidati), separated from each other by a crucial depression. The upper molars have four cusps situated at the angles of the masticating surface: of these the internal and anterior cusp is the largest, and is frequently connected with the posterior external cusp by a low oblique ridge. In the upper wisdom-teeth, the two internal tubercles are usually blended together. The crowns of the lower molars, which are larger than those of the upper, have five cusps, the additional one being placed between the two posterior cusps, and rather to the outer side: this is especially evident in the lower wisdom-teeth, in which the crown is smaller and rounder than in the others. The *fangs* of all the molar teeth are multiple. In the two anterior molars of the upper jaw, they are three in number, viz. two placed externally, which are short, divergent, and turned towards the antrum of the superior maxilla; and a third or internal fang, which is larger and longer, and is directed towards the palate, the posterior border of which extends as far back as that of the posterior external fang. This third fang is often slightly grooved, especially when the two internal cusps are very distinct, and sometimes it is divided into two smaller fangs. The two anterior molars of the lower jaw have each two fangs, one anterior, the other posterior, which are broad, compressed, and grooved on the faces that are turned towards each other, as if each consisted of two fangs fused together: they have an inclination or curve backwards in the jaw, and are slightly divergent, or sometimes parallel, or even nearly in contact with each other: more rarely one or both of them is divided into two smaller fangs. In the wisdom-teeth of both jaws the fangs are often collected into a single irregular conical mass, which is either directed backwards in the substance of the jaw, or curved irregularly: this composite fang sometimes shows traces of subdivision, and there are occasionally two fangs in the lower tooth and three in the upper.

The bicuspid and the molar teeth, from the breadth and uneven form of their crowns, are fitted for bruising, crushing, and grinding the food in mastication.

The range of teeth in each jaw forms a nearly uniform curve, which is not broken by any intervals, as is the case in the dental apparatus of many animals, even in the Quadrumana. The upper dental arch is rather wider than the lower one, so that the teeth of the upper jaw slightly overhang those of the lower. This is owing principally to the fact that the lower teeth are placed either vertically, as in front, or are inclined somewhat inwards, as is seen behind and at the sides, while the corresponding teeth of the upper jaw have an inclination forwards in front, and outwards

behind. While there is a slight diminution in the height of the exposed parts of the teeth from the incisors backwards to the wisdom-teeth, there is in man a general uniformity in the amount of projection of the crowns throughout the whole series. In consequence of the large proportionate breadth of the upper central incisors, the other teeth of the upper jaw are thrown somewhat outwards, so that in closure of the jaws the canine and bicuspid teeth come into contact partly with the corresponding lower teeth and partly with those next following; and in the case of the molar teeth each cusp of the upper lies behind the corresponding cusp of the lower teeth. Since, however, the upper wisdom-teeth are smaller than those below, the dental ranges terminate behind nearly at the same point in both jaws.

The Milk-teeth.—The temporary incisor and canine teeth resemble those of the permanent set in their general form; but they are of smaller dimensions. The temporary molar teeth present some peculiarities. The hinder of the two is much the larger; it is the largest of all the milk-teeth, and is larger even than the second permanent bicuspid, by which it is afterwards replaced. The *crown* of the first upper milk molar has only three cusps,

Fig. 542.

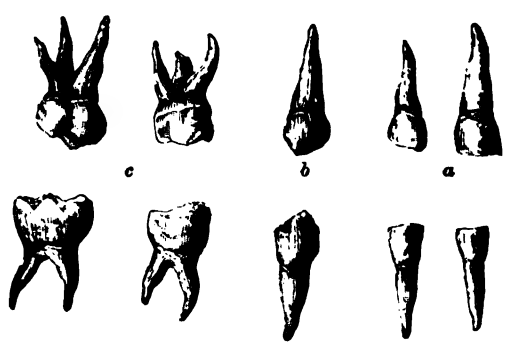


Fig. 542.—Milk Teeth of the Right Side of the Upper and Lower Jaws.
a, the incisors; *b*, the canines; *c*, the molar teeth.

two external and one internal; that of the second has four distinct cusps. The first lower temporary molar has four cusps, and the second five, of which in the latter case three are external. The *fangs* of the temporary molars resemble those of the permanent set, but they are smaller, and are more divergent from the neck of the tooth.

Structure.—On making a section of a tooth, the hard substance of which it is composed is found to be hollow in the centre. The form of the cavity bears a general resemblance to that of the tooth itself: it occupies the interior of the crown, is widest opposite to or a little above the neck, and extends down each fang, at the point of which it opens by a small orifice. In the crown of the incisor teeth the cavity is prolonged into two fine linear canals, which proceed one to each corner of the crown; in the bicuspid and molar teeth it advances a short distance into each cusp. In the case of a root formed by the blending of two or more fangs, as occurs occasionally in the wisdom-teeth, each division has a separate canal prolonged down to its apex.

The central cavity of a tooth is called the *pulp cavity*, because it is occupied and accurately filled by a soft, highly vascular, and sensitive substance,

Fig. 543.

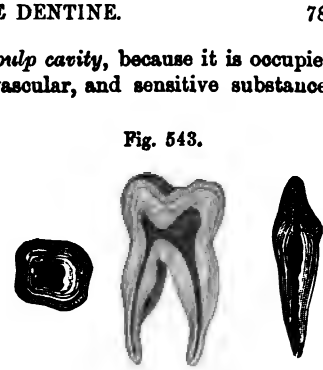


Fig. 543.—SECTIONS OF AN INCISOR AND MOLAR TOOTH.

The longitudinal sections show the whole of the pulp cavity in the incisor and molar teeth, its extension upwards within the crown and its prolongation downwards into the fangs with the small aperture at the point of each; these and the cross section show the relation of the dentine and enamel.

called the *dental pulp*. This pulp consists of areolar filaments, amongst which numerous nuclei and cells are rendered visible by the action of acetic acid. It is well supplied with vessels and nerves, which are derived from the internal maxillary artery and the fifth pair, and which enter the cavity through the small aperture at the point of each fang.

Fig. 544.

Fig. 544.—MAGNIFIED LONGITUDINAL SECTION OF A BICUSPID TOOTH (after Retzius).

1, the ivory or dentine, showing the direction and primary curves of the dental tubuli; 2, the pulp-cavity with the small apertures of the tubuli into it; 3, the cement or crusta petrosa covering the fang as high as the border of the enamel at the neck, exhibiting lacunæ; 4, the enamel resting on the dentine; this has been worn away by use from the upper part.

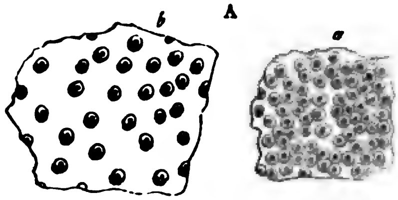
The solid portion of the tooth is composed of three distinct substances, viz. the proper dental substance, *ivory* or *dentine*, the *enamel*, and the *cement* or *crusta petrosa*. The dentine constitutes by far the larger part of the hard substance of a tooth; the enamel is found only upon the exposed part or crown; and the cement covers with a thin layer the surface of the implanted portion or fang. A fourth variety of tissue, *osteodentine*, is formed within the dentine, at the expense of the pulp, as age advances.

A. The *dentine*, (Owen,) forming the principal mass or foundation of the body and root of a tooth, gives to both of these parts their general form, and immediately encloses the central cavity. It resembles very compact bone in its general aspect and chemical relations, but is not identical with it in structure, or in the exact proportions of its earthy and animal constituents.

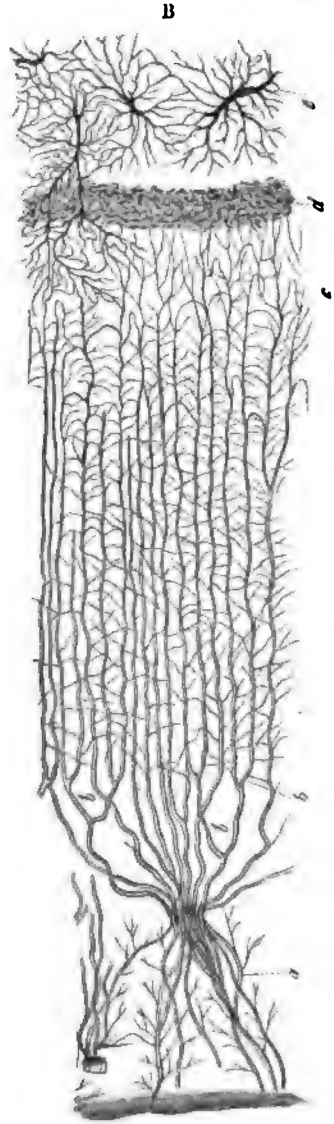
According to the analyses of Berzelius and Bibra, the dentine of human teeth consists of 28 parts per cent. of animal, and 72 of earthy matter. The former is resolvable into gelatin by boiling. The composition of the latter, according to Bibra, is as follows, viz., phosphate of lime 66·7 per cent., carbonate of lime 3·3, phosphate of magnesia and other salts, including a trace of fluoride of calcium, 1·8. Berzelius found 5·3 carbonate of lime.

Fig. 545.

A



B



Examined under the microscope, dentine is seen to consist of an immense number of very fine tubes, imbedded closely together in a hard intertubular matrix, and having the appearance of possessing distinct parietes. These *dental tubules* open at their inner ends into the pulp cavity, the wall of which presents very numerous minute orifices over the whole of its inner surface. From thence they pass in a radiated manner

Fig. 545.—Sections of Dentine (from Kölliker).

A, highly magnified cross sections of the tubuli of dentine. $\frac{450}{1}$ *a*, from a part in which the tubuli are very closely set; *b*, from a part where they are widely set.

B, longitudinal section of the root. $\frac{350}{1}$ *a*, the dental tubes near the inner surface of the dentine with few tubuli; *b*, subdivision of tubuli; *c*, looped disposition of the tubuli; *d*, granular layer consisting of small dental globules at the margin of the dentine; *e*, lacunæ of the cement, one of them connected by tubuli with those of the dentine.

through every part of the ivory towards its periphery. In the upper portion of the crown they have a vertical direction; but towards the sides, and in the neck and root, they become gradually oblique, then horizontal, and are finally even inclined downwards towards the point of the fang. The course of the tubules is not straight, but each describes, in passing from the central to the peripheral part of the dentine, two or three gentle curves (*primary* curvatures, Owen), and is besides bent throughout its whole length into numerous fine undulations, which follow closely one upon another; these are the *secondary* curvatures. The curvatures of adjacent tubules so

far correspond, that the tubes are on the whole nearly parallel, being only slightly divergent as they pass towards the surface; and as they divide several times dichotomously, and at first without being much diminished in size, they continue to occupy the substance of the dentine with nearly equidistant tubes, and thus produce, when seen in fine sections of the tooth made parallel to their course, a striated appearance, as if the dentine were made up of fine parallel fibres. The concurrence of many of these parallel curvatures of the dental tubuli produces, by the manner in which they reflect the light, an appearance of concentric undulations in the dentine, which may be well seen with a low magnifying power. This, however, is not to be confounded with another set of curved marks called contour lines, which depend on conditions of the matrix, and will be afterwards described. The average diameter of each tubule near its inner and larger end is $\frac{1}{4500}$th of an inch, and the distance between adjacent tubules is about two or three times their width. (Retzius.) From their sides numerous immeasurably fine branches are given off, which penetrate the hard intertubular substance, where they either anastomose or terminate blindly. These lateral ramuscles are said to be more abundant in the fang. Near the periphery of the ivory they are very numerous, and, together with the main tubules themselves, which there, by rapid division and subdivision, also become very fine, terminate by joining together in loops, or end in little dilatations, or in the cells of the granular layer to be described.

The dental tubules, when highly magnified, appear like dark lines against transmitted light, but are white when seen upon a black ground. Their tubular character is proved by the fact that ink, or other coloured fluids, together with minute bells of air, can be made to pass along them, in sections of dry teeth. Their walls, in transverse sections, may often appear thicker than they are in reality, owing to a certain length of the tubes being seen in the section: but if the orifice of the canal is brought exactly into focus, the wall appears as only a very thin, yellowish border; and, indeed, Kölliker denies the existence of any wall distinct from the matrix. From the researches of Nasmyth, Tomes and Kölliker, it appears that in the recent state the tubules are filled with substance (dental fibres), continuous with the pulp of the tooth: and it is suggested by Tomes that this is not only subservient to the nutrition of the dentine, but probably also confers on it a certain degree of sensibility. It has been noticed, indeed, that the dentine is more sensitive near the surface than deeper in its substance,—a fact not easily intelligible on the supposition that the sentient tissue is confined to the pulp cavity.

In the temporary, and sometimes even in the permanent teeth, the tubules are constricted at short intervals, so as to present a moniliform character. The terminal branches of tubules are occasionally seen to pass on into the cement which covers the fang, and to communicate with the small ramified canals of the characteristic lacunæ found in that osseous layer. Tubules have likewise been observed by Tomes passing on into the enamel, more especially in the teeth of marsupial animals, but in a less marked degree in human teeth.

The *intertubular substance* is translucent. The animal matter which remains in it, after the earthy matter has been removed by an acid, exhibits a tendency to tear in the direction of the tubules, but is in reality a homogenous substance, deposited in a laminated manner. This was shown by Sharpey, who observed that in the softened teeth of the cachalot or sperm whale the animal substance was readily torn into fine lamellæ, disposed parallelly with the internal surface of the pulp cavity, and there-

fore across the direction of the tubules. In these lamellæ the sections of the tubules appeared as round or oval apertures, the lamellæ having the same relation to the tubules as those of true bone to the canaliculi. The same tendency to lamination may be exhibited by boiling a longitudinal section of tooth with caustic potash, after which it presents closely set, short, and regular fissures, lying at right angles to the tubules, throughout the extent of the dentine. (Cleland).

Fig. 546.

Fig. 547.

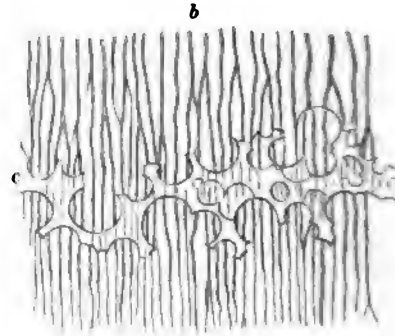


Fig. 546.—Vertical Section of the Upper Part of an Incisor Tooth (from Kölliker). $\frac{1}{1}$

a, the pulp-cavity; *b*, dentine or tubular substance; *c*, arched contour lines with interglobular spaces; *d*, cement; *e*, enamel with an indication of the direction of the columns; *f*, coloured lines of the enamel.

Fig. 547.—A Small Portion of the Dentine with Interglobular Spaces (from Kölliker). $\frac{350}{1}$

b, the tubules; *c*, the interglobular spaces filled with air.

A laminated structure of a more distinct description has been observed in the dentine of the crown, giving rise to the appearances in longitudinal sections termed *contour lines*. Czermak states that transverse sections of the tooth present concentric lines resembling the year-rings of wood: and Salter has shown that decalcified specimens readily break up in these lines; the crowns of the teeth consisting of a series of superimposed hollow cones: the intervals between their strata, in longitudinal sections, appearing as contour markings, in transverse sections as annular lines; in both cases corresponding with the surface of the pulp, as it existed during the formation of the tooth. The contour markings, when examined with the microscope, are seen to be caused by irregularities of the intertubular tissue, which, opposite these marks, presents the appearance of spaces or clefts bounded by globular masses of the ordinary tubular and dense substance. These globules vary in size from $\frac{1}{250}$th to $\frac{1}{10000}$th of an inch; the largest being in the crown, the smallest in the fang. The tubuli pass through these globules, and appear to be continuous in direction across the interspaces from one globule to another.

Another kind of irregularity in the structure of the dentine gives rise to the *granular layer* of Purkinje; the peculiarity of which consists in the presence of a number of minute cell-like cavities, which break up the uniformity of the matrix, and by branches anastomose one with another and receive terminations of dental tubuli. They are found principally in a layer beneath the cement, and also beneath the enamel. The circumstance of their forming connections with the tubules points to a difference in nature between these cavities and the much larger interglobular spaces.

The surface of the dentine where it is in contact with the enamel is marked by undulating grooves and ridges, and also by numerous minute hexagonal depressions, to which the microscopic fibres of the enamel are accurately adapted.

B. The *enamel* is that hard white covering which encrusts and protects the exposed portion or crown of a tooth. It is the hardest of all the dental tissues, but it is gradually worn down by protracted use. It is thickest on the grinding surface and cutting edges of the teeth, and becomes gradually thinner towards the neck, where it ceases. Its extent and thickness are readily seen on charring the tooth, by which the dentine becomes blackened, whilst the enamel, owing to the very small quantity of animal matter in its composition, remains white. According to Bibra it contains of earthy constituents 96·5 per cent., viz. phosphate of lime with traces of fluoride of calcium 89·8, carbonate of lime 4·4, phosphate of magnesia and other salts 1·3; and has only 3·5 per cent. of animal matter. Berzelius, however, gives the proportion of carbonate of lime as 8, and of animal matter as only 2 per cent.

Fig. 548.

Fig. 548.—Thin Section of the Enamel and a Part of the Dentine (from Kölliker). $\frac{350}{1}$

a, cuticular pellicle of the enamel; *b*, enamel fibres or columns with fissures between them and cross striæ; *c*, larger cavities in the enamel communicating with the extremities of some of the tubuli (*d*).

The enamel is made up entirely of very hard and dense microscopic fibres or prisms, composed almost wholly of earthy matter, arranged closely together, side by side, and set by one extremity upon the subjacent surface of the dentine. On the summit of the coronal portion of the tooth these enamel fibres are directed vertically, but on the sides they are nearly horizontal. As seen in a section they are disposed in gently waving lines, parallel with each other, but not so regular as the curvatures of the tubuli of the dentine, with which they have no agreement. The concurrence of these parallel curvatures produces, as in the case of the dentine, an appearance of concentric undulations in the enamel, which may be seen with a lens of low power. A series of concentric lines is likewise to be seen crossing the enamel fibres, as the contour lines cross the dentine: these are termed *coloured lines* from their brown appearance, but they seem rather to depend on lamination than on pigmentary deposit. Minute fissures not unfrequently exist in the deep part of the enamel, which run between

clusters of the fibres down to the surface of the dentine ; and other much larger and more evident fissures are often observed leading down from the depressions or crevices between the cusps of the molar and premolar teeth. The surface of the enamel, especially in the milk-teeth, is marked by transverse ridges, which may be distinguished with a common magnifying glass.

Fig. 549.

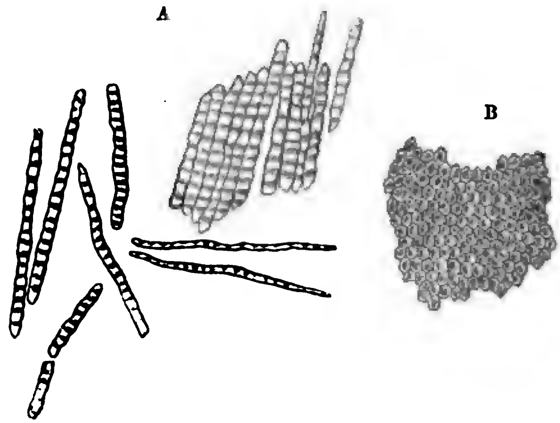


Fig. 549.—ENAMEL FIBRES (from Kölliker). $\frac{350}{1}$

A, fragments and single fibres of the enamel, isolated by the action of hydrochloric acid. B, surface of a small fragment of enamel, showing the hexagonal ends of the fibres.

The enamel fibres have the form of solid hexagonal prisms. Their diameter varies slightly, and is ordinarily about $\frac{1}{5000}$th of an inch. They are marked at small intervals by dark transverse lines. According to Tomes, the fibre is not in all cases solid, but has occasionally an extremely minute cavity in part or in the whole of its length, which is best seen in newly-developed enamel, but is also visible in adult teeth. The inner ends of the prisms are implanted, as it were, into the minute hexagonal depressions found on the surface of the dentine, whilst the outer ends, somewhat larger in diameter, are free, and present, when examined with a high magnifying power, a tesselated appearance.

When submitted to the action of dilute acids, the enamel is almost entirely dissolved, and leaves scarcely any discernible traces of animal matter. Near the deep surface this is rather more abundant, according to the observations of Retzius, who conceived that it there aided in fixing the enamel fibres. By the action of an acid, the enamel of newly-formed or still growing teeth may be broken up, and its structural elements more easily distinguished. The prisms are then found to have interposed between them a delicate membranous structure, forming sheaths in which the calcareous matter is deposited. As this latter accumulates, the membranous structure becomes almost or entirely obliterated, and the now earthy prisms are inseparably consolidated. Each membranous sheath, according to Tomes, contains a line of granular cells or masses, arranged in single series like the sarcous elements in muscular fibres, and thus occasioning the transverse markings.

It is also found, on treatment with acid, that a very thin membrane called by Kölliker "cuticle of the enamel,"—and by Busk and Huxley "*Nasmyth's membrane*" (after its discoverer), entirely covers the enamel upon its outer surface. This membrane, which is calcified in the natural state, forms a protective covering to the enamel. Berzelius and Retzius say that a similar membrane also exists between the enamel and the dentine, but Kölliker has been unable to find any in that situation.

c. The *crusta petrosa* or *cement* is the third substance which enters into the formation of the teeth. This is a layer of true bone, slightly modified in structure, and investing that part of the dentine which is not protected by the enamel. It covers the whole fang, towards the lower end of which it becomes gradually thicker, and is especially developed at the apex, and along the grooves of the compound fangs. Besides this, the calcified membrane or cuticle on the surface of the enamel has been regarded by various writers as a coating of cement in that situation, the representative of the coronal cement on the compound teeth of many herbivorous animals. As life advances, the cement generally becomes thicker, especially near the apex of the fang, where it sometimes blocks up the orifice leading into the pulp cavity.

The crusta petrosa contains cells and canaliculi resembling those of bone; they are placed lengthwise around the fang, and give off minute radiated ramifications, which are often found to proceed from one side only of a cell, towards the *periodontal* surface (Tomes). In the deeper layers of the cement the fine canaliculi sometimes anastomose with some of the terminal tubules of the subjacent dentine. Where the cement is very thick it may contain vascular canals, analogous to the Haversian canals of bone. On the deciduous teeth the cement is thinner and contains fewer cells. It has been shown by Sharpey that perforating fibres, similar to those of ordinary bone, run abundantly through the cement. In chemical composition it resembles bone, and contains 30 per cent. of animal matter. The cement is, according to some, extremely sensitive at the neck of the tooth, if it be exposed by

Fig. 550.

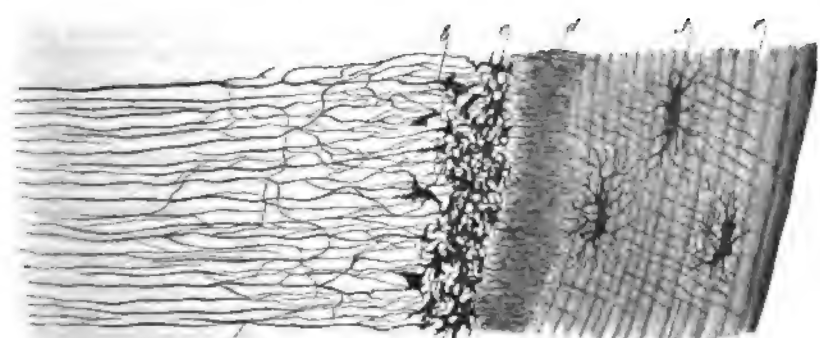


Fig. 550.—Section of a Portion of the Dentine and Cement from the Middle of the Root of an Incisor Tooth (from Kölliker). $\frac{350}{1}$

a, dental tubuli ramifying and terminating, some of them in the interglobular spaces (*b* and *c*), which resemble somewhat bone lacunæ; *d*, inner layer of the cement with numerous closely set canaliculi; *e*, outer layer of cement; *f*, lacunæ; *g*, canaliculi.

retraction of the gum. By its connection with the surrounding membranous structures it contributes to fix the tooth in the socket. It is the seat of the bony growths or exostoses sometimes found upon the teeth.

D. Osteodentine (Owen), *secondary dentine* (Tomes), or the *horny substance* of Blumenbach, is a hard substance which begins to be deposited on the inner surface of the dentine after the age of twenty years or later, so that the central cavity of a tooth becomes gradually diminished in size, whilst the pulp slowly shrinks or disappears. This additional substance, formerly regarded as an extension of the cement into the interior of the tooth, has been shown to have a distinct structure, in part resembling dentine, and in part bone. It is traversed by canals, which contain blood-vessels, and are surrounded by concentric lamellæ, like the Haversian canals of bone. From these canals, numerous tubules radiate in all directions, larger than the canaliculi of bone, resembling, in this respect, and also in their mode of ramification, the tubes of the dentine. This newly added structure may or may not coalesce with the previously formed dentine; it appears to be produced by a slow conversion of the dental pulp.

Among special works on the teeth may be noticed, Retzius, in Müller's Archiv, 1837; Nasmyth, Researches on the Teeth, 1839; Owen, Odontography, 1840-45; Tomes, Lectures on Dental Physiology and Surgery, 1848, also in the Phil. Transactions, 1849 and 1850, and in Quart. Journ. of Micr. Science, 1856; Salter, in Quarterly Journal of Microscopic Science, 1853, in Guy's Hospital Reports, third series, vol. i.; and in Trans. Path. Soc., 1854 and 1855; Czermak in Zeitschrift für wissensch. Zoologie, 1850; Huxley in Quarterly Journal of Microscopic Science, 1853.

DEVELOPMENT OF THE TEETH.

Although the general phenomena of the growth and succession of the teeth had received considerable attention from a variety of anatomists, the observations of Arnold and Goodsir, made independently of each other, more especially the latter, were the first to give precision to our knowledge concerning their origin and the earlier stages of their formation. More recent researches have, it is true, shown that their account of the primordial condition of the dental germs may require some modification; but nevertheless these authors were the first to establish the primordial connection of the teeth with the mucous membrane covering the edges of the maxillary arches, and Goodsir was the first to give a consistent view of the earlier steps of the formative process in the temporary and permanent series of teeth. (Arnold in Salzbürger Med. Zeitung, 1831; Goodsir in Edin. Med. and Surg. Journal, 1839.) The changes which take place in the bones of the jaws relate only to the formation of the sockets of the teeth. In their earliest condition these bones present no appearance of alveoli, but, concurrently with certain changes in the mucous membrane, to be immediately described, a wide groove is developed along the edge of the jaw, which gradually becomes deeper, and is at length divided across by thin bony partitions, so as to form a series of four-sided cells. These bony septa are not distinctly formed until near the fifth month of fœtal life. By the subsequent growth of the bone, these cavities or loculi are gradually closed round, except where they remain open at the edge of the jaw. By the end of the sixth month they are distinctly formed, but continue afterwards, in proportion to the growth of the teeth, to increase in size and depth, by the addition of new matter which widens and deepens the jaw.

The first stages in the development of the teeth, as observed by Arnold and Goodsir, consist of certain changes in the mucous membrane cover-

ing the borders of the maxillæ. About the sixth week of embryonic life, a depression or groove, having the form of a horse-shoe, appears along the edge of the jaw, in the mucous membrane of the gum; this is the *primitive dental groove* (Goodsir). From the floor of this groove (supposed to be represented in a transverse section, in the diagrammatic figure 551, 1)

Fig. 551.

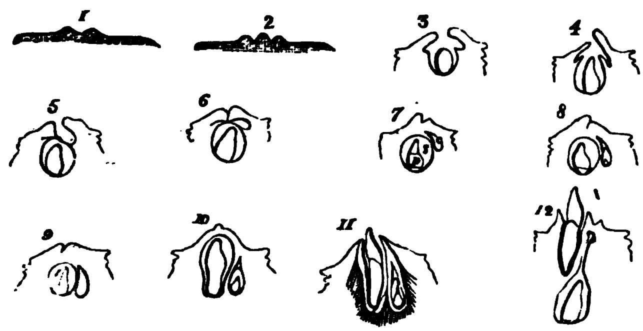


Fig. 551.—Diagrammatic Outlines of Sections through the Dental Germs and Sacs, at Different Stages of Development (from Goodsir).

1, the primitive dental groove of the gum cut across in a fœtus of about six weeks; 2, a papilla rising within the dental groove; 3, 4, and 5, represent the follicular stage in which the papilla (or future tooth-pulp) is seen sunk within the follicle, and the lips of the follicle or opercula advancing towards each other gradually meet and close in the follicle; 5, may be looked upon as representing the section indicated by the line *a b*, in fig. 559, through the sac of an incisor tooth, in which a lunated depression (*c*) is left behind; in 6, the lips of the groove are seen to come together; in 7, the union of the lips being complete, the follicle becomes a closed sac *s*, containing the dental pulp *p*, and having behind it the lunated depression *c*, now also enclosed, and forming the cavity of reserve for the germ of the corresponding permanent tooth; in the remaining outlines, 8 to 12, are shown the commencement of the cap of dentine on the pulp, the subsequent steps in the formation of the milk tooth, and its eruption through the gum (11); also the gradual changes in the cavity of reserve, the appearance of its laminæ and papilla, its closure to form the sac of the permanent tooth, its descent into the jaw, behind and below the milk tooth, and the long pedicle (12) formed by its upper obliterated portion.

a series of ten papillæ, as at 2, arise in succession in each jaw, and constitute the germs or rudimentary pulps of the milk-teeth. These pulps or papillæ are processes of the mucous membrane itself, and not mere elevations of its epithelium. The order in which they appear is very regular. The earliest is that for the first milk molar tooth: it is seen at the seventh week, as soon as the dental groove is formed; at the eighth week that for the canine tooth appears; the two incisor papillæ follow next, at about the ninth week, the central one before the lateral; lastly, the second molar papilla is visible at the tenth week, at which period this, the *papillary stage* of the rudiments of the teeth is completed. The papillæ in the upper jaw appear a little earlier than those in the lower jaw.—In the next place, the margins of the dental groove become thickened and prominent, especially the inner one; and membranous septa or prolongations of the mucous membrane pass across between the papillæ from one margin to the other, so as to convert the bottom of the groove into a series of follicles, each containing one of the papillæ. These changes constitute the *follicular stage*; they take place in the same order as that in which the papillæ make their appearance, and are completed about the fourteenth week. During the early part of this

period the papillæ grow rapidly, they begin to show peculiarities of form, and project from the mouths of the follicles. Soon, however, the follicles become deeper, so as to hide the papillæ, which now assume a shape corresponding with that of the crowns of the future teeth. Small laminæ or opercula of membrane are then developed from the sides of each follicle, their number and position being regulated, it is said, by the form of the cutting edges and tubercles of the coming teeth: the incisor follicles having two laminæ, one external and one internal; the canine, three, of which two are internal; and the molars, four or five each.—The lips of the dental groove, as well as the opercula, now begin to cohere over the follicles from behind forwards, the posterior lip being very much thickened; the groove itself is thus

Fig. 552.

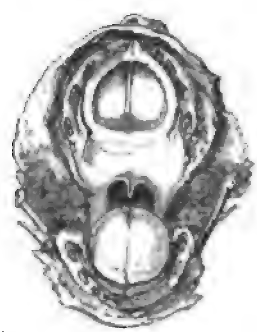


Fig. 552.—Enlarged View of the Upper and Lower Dental Arches of a Fœtus of about Fourteen Weeks.

This specimen shows the follicular stage of development of all the milk teeth as described by Goodsir; in each follicle the papilla is seen projecting; but this exposure of the papillæ and the cavity of the follicles probably arises from the accidental loss of the epithelial covering.

gradually obliterated, the follicles are converted into closed sacs, and the *saccular stage* of the milk-teeth is thus completed about the end of the fifteenth week. Certain lunated depressions, which are formed one behind each of the milk-follicles about the fourteenth week, escape the general adhesion of the lips of the groove. From these depressions, as will be afterwards described, the sacs of the ten anterior permanent teeth are subsequently developed.

The first stages in the development of the teeth here described, the superficial origin and open condition of the dental sacs, and the free papillary commencement of the pulps, have been denied in recent years by Guillot, and by Robin and Magitot, who assert that the sacs with their contents make their first appearance in the submucous tissue, and are from the first closed sacs (Guillot in Annales des Sciences Naturelles, vol. ix., 1859; Robin and Magitot in Journal de la Physiologie, 1860, vol. iii., pp. 130 and 663). The observations of Kölliker, however, seem to furnish a clue to the explanation of what has been seen by these authors, at the same time that they confirm, in its most important features, Goodsir's mode of viewing the phenomena. In the fœtal lamb and calf, the first step in the formation of the tooth-germ, observed by Kölliker, consists in a depression of a part of the deepest layer of the epithelium into the subjacent mucous membrane. This depression, which, in common with Huxley, he regards as the commencement of the fœtal structure known as the enamel organ, to be afterwards described, widens subsequently, so as to become flask-shaped, remaining connected with the deep surface of the epithelium by a narrow neck. In the next stage the dental papilla rising from the surface of the mucous membrane, projects into, or indents the deepest side of the epithelial process or future enamel organ, and the dental sac is formed at a somewhat later period in the surrounding substance of the mucous membrane. In these animals, therefore, the epithelium of the edge of the jaw covers in completely the enamel germ or primary tooth-follicle.

In man, Kölliker was unable to discover a similar arrangement, but found matters very much in the disposition described by Goodsir; that is, the follicles open, situated in a dental groove of the jaw, and containing at their deepest part the dental papillæ developed from the mucous membrane. But he conceives it not improbable that in Goodsir's specimens, as well as in his own, the whole of the epithelium had been abraded, and that the follicles and papillæ were thus unnaturally opened to the surface.

Fig. 553.

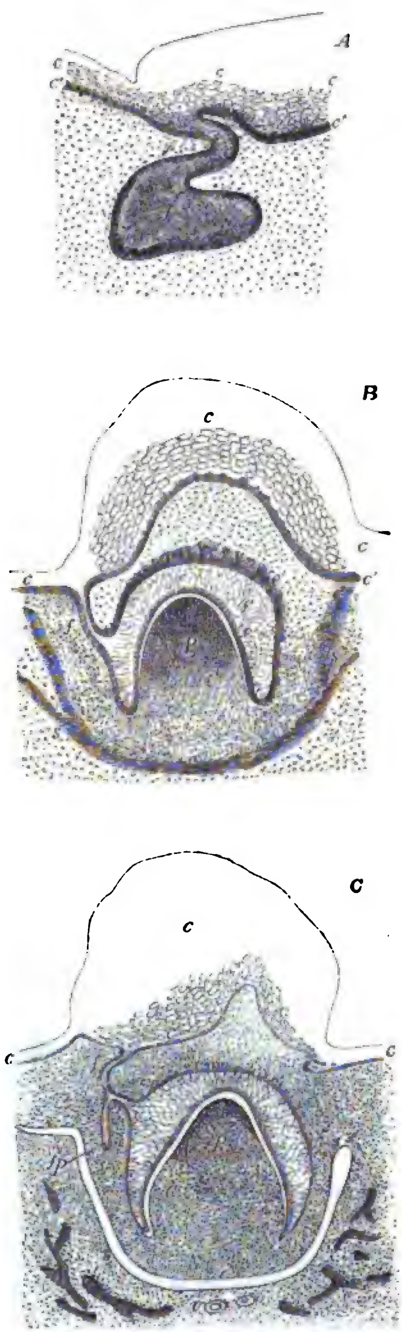


Fig. 553.—Diagrams of the Mode of Origin of the Dental Germ in the Ruminant (after Kölliker).

The three figures represent transverse sections of the gum and a part of the jaw at or shortly after the period of the formation of the germ, and are designed chiefly to show the relation of the germ to the epithelium.

A, represents the state in a very early condition, when the primitive dental follicle of a milk or temporary tooth has been formed by a depression from the deep layer of the epithelium.

B, represents a later stage, when the tooth papilla has risen from the surface of the mucous membrane, and has inflected the primitive dental follicle.

C, represents a more advanced stage in which the dental sac has begun to be formed.

c, the superficial thick epithelium of the gum only sketched in outline; *c'*, the deep layer of cylindrical cells; *f*, the primitive tooth-follicle; *f'*, its cellular or granular contents and cavity; *p*, the dental papilla, and afterwards tooth-pulp; *e*, the inner inflected layer of the wall of the primitive follicle forming the inner part of the enamel organ; *e'*, the outer wall of the same with the epithelial sprouts shooting into the tissue above; *s*, the commencement of the dental sac; *fp*, the follicle of the corresponding permament tooth.

Waldeyer has shown by more recent observations, that in the human embryo the teeth arise in a manner essentially the same as that described by Kölliker in the ruminant. (Waldeyer, üb. die Entwick. der Zähne, Zeitsch. fur. ration. Medicin, 1865, and Henle's Bericht, &c. for 1864, p. 81.)

The *dental sacs*, after the closure of the follicles, continue to enlarge, as do also their contained papillæ. The walls of the sacs, which soon begin to thicken, consist of an outer fibro-areolar membrane, and an internal highly vascular layer, lined by epithelium; their blood-vessels are derived partly from the dental arteries which course along the base of the sacs, and partly from those of the gums.

The papillæ, now the dental pulps, acquire a perfect resem-

blance to the crowns of the future teeth, and then the formation of the hard substance commences in them. This process begins very early, and by the end of the fourth month of fœtal life thin shells or caps of dentine are found on all the pulps of the milk-teeth, and a little later on that of the first permanent molar, while at the same time the coating of enamel begins to be deposited on each. The cap of dentine increases in extent by a growth around its edges, and in thickness by additions in its interior, at the expense of the substance of the pulp itself, which decreases in proportion. This growth of the tooth continues until the crown is completed of its proper width, and then the pulp undergoes a constriction at its base to form the cervix of the tooth, and afterwards elongates and becomes narrower, so as to serve as the basis of the fang. Sooner or later, after the completion of the crown, this part of the tooth appears through the gum, whilst the growth of dentine to complete the fang is continued at the surface of the elongating pulp, which gradually becomes encroached upon by successive formations of hard substance, until only a small cavity is left in the centre of the tooth, containing nothing but the reduced pulp, supplied by slender threads of vessels and nerves, which enter by a small aperture left at the point of the fang after the dentine is completed. In the case of teeth having complex crowns and more than a single fang, the process is somewhat modified. On the surface of the dental pulp of such a tooth, as many separate caps or shells of dental substance are formed as there are eminences or points; these soon coalesce, and the formation of the tooth proceeds as before as far as the cervix. The pulp then becomes divided into two or more portions, corresponding with the future fangs, and the ossification advances in each as it does in a single fang. A horizontal projection or bridge of dentine shoots across the base of the pulp, between the commencing fangs, so that if the tooth be removed at this stage and examined on its under surface, its shell presents as many apertures as there are separate fangs. In all teeth, the pulp originally adheres by its entire base to the bottom of the sac, but when more than one fang is to be developed, the pulp is, as it were, separated from the sac in certain parts, so that it comes to adhere at two or three insulated points only, whilst the dentine continues to be formed along the intermediate and surrounding free surface of the pulp.

Formation of the hard tissues of the teeth.—Previously to the commencement of ossification, the primitive pulp is found to consist of microscopic nucleated cells (pulp granules, Purkinje), more or less rounded in form, and imbedded in a clear

Fig. 554

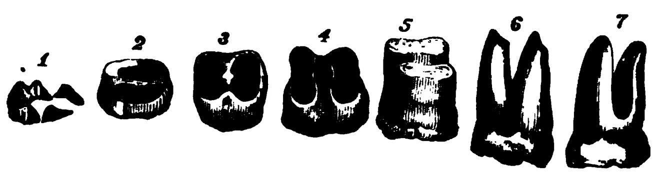


Fig. 554.—Different Stages in the formation of a Molar Tooth with Two Fangs (from Blake).

1, the distinct caps of dentine for five crowns in the earliest stage of formation; in 2, and the remaining figures, the crown is downwards; in 2 and 3, the formation of the crown having proceeded as far as the neck, a bridge of dentine stretches across the base of the tooth-pulp; and in 4, the division of the fangs is thus completed; in 5, 6, and 7, the extension takes place in the fangs.

matrix containing a few very fine molecules, thinly disseminated in it. At the exterior of the pulp, the cells become elongated, and arranged perpendicularly to the

Fig. 555.

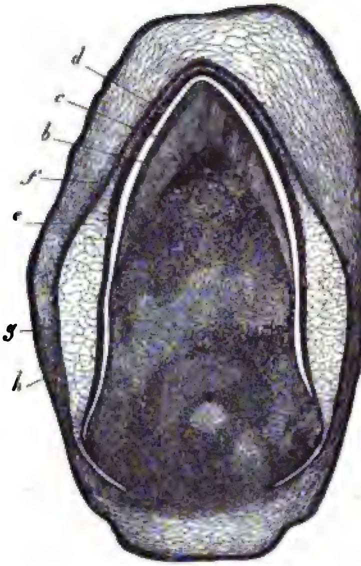


Fig. 555.—Vertical Transverse Section of the Dental Sac, Pulp, &c., of a Kitten (from Kölliker after a preparation by Tiersch). $\frac{14}{1}$

a, dental papilla or pulp, the outer darker part consisting of the dentine cells; *b*, the cap of dentine formed upon the summit; *c*, its covering of enamel; *d*, inner layer of epithelium of the enamel organ; *e*, gelatinous tissue; *f*, outer epithelial layer of the enamel organ; *g*, inner layer, and *h*, outer layer of the dental sac.

surface, so as to form a tolerably regular layer, resembling a columnar epithelium. The pulp contains white areolar fibres, without any elastic or yellow tissue, and it is highly vascular. The capillary vessels are most abundant at the points where ossification is to commence; they form a series of loops between rows of cells arranged in a radiate manner, but they do not reach the surface. Besides this, the entire pulp is covered by a fine pellucid homogeneous membrane, named the *preformative membrane* (Purkinje, Raschkow), or *basement membrane*. The space between the pulp and the wall of the sac is occupied by a delicate substance accurately applied to its surface. This is the *outer pulp* of Hunter, termed also the *enamel organ* (*organon adamantinæ*, Purkinje), being generally considered to be connected with the formation of the enamel. It presents three layers; viz., externally, an epithelial layer with prominences which fit in between vascular processes of the surrounding mucous membrane; internally, a layer of cylindrical nucleated cells, named the *enamel membrane*, resting on the preformative membrane; and between these, a bulky substance, consisting of small stellate cells anastomosing by long processes, and having the large meshes between them filled with clear fluid. This structure was formerly supposed to be similar to the primitive pulp; but, as was first stated by Huxley and since confirmed by Kölliker, the whole enamel organ is epithelial in nature, being derived by invagination from the cuticle.

The dentine is formed at the surface of the pulp, beneath the preformative membrane, but the precise manner in which it is derived from the soft tissues is still a matter for investigation. According to Purkinje, Retzius, and Raschkow, the preformative membrane is the part which first undergoes calcification, and afterwards the tissue of the pulp immediately beneath it. On gently separating the newly-formed cap of dentine from the formative pulp, in the growing teeth of the human subject or of animals, and examining it under the microscope, the elongated cells of the pulp are found adhering in numbers to the inner surface of the newly-formed dentine. Owen states that the nuclei of the elongated cells, having themselves become lengthened, divide both longitudinally and transversely to develop secondary cells which continue included within the primary cells. The secondary cells then elongate, and together with their nuclei join end to end. Calcification proceeds in all parts, except in the nuclei of the secondary cells which remain as the cavities or lumina of the tubes; the walls of the secondary cells are supposed to form the parietes of the tubes, and the material between the secondary cells together with the walls of the primary cells to be converted into the intertubular substance. The bifurcation of the tubuli is said to result from the junction of two

secondary cells with a single one in a deeper layer of the pulp; and the constricted or moniliform appearance of the tubuli already mentioned as having been seen by some observers in growing or even in mature teeth, is thought to depend on an imperfect

Fig. 556.

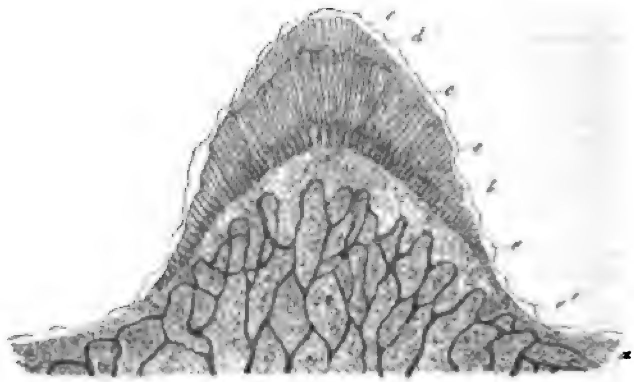


Fig. 556.—VERTICAL SECTION THROUGH THE POINT OF A HUMAN FŒTAL MILK TOOTH, IN WHICH THE FORMATION OF THE DENTINE AND ENAMEL HAS RECENTLY COMMENCED (from Kölliker after Lent). [14]

a, dental pulp with blood-vessels; *b*, the dentine cells upon its surface; *c*, the cap of dentine which has been formed on the summit, the tubuli being shown as prolongations from the tapering extremities of the dentine cells; *d*, the enamel begun to be deposited; *e*, membranous layer, membrana præformativa of Huxley.

coalescence of the nuclei. In the teeth of young animals, Tomes has noticed the division of the cells and their subsequent coalescence to form the tubes, but he has failed to recognise the existence of primary cells including secondary ones. Lent finds that the superficial elongated cells of the dentinal pulp send off from their free ends long slender processes which form the tubes of the dentine, and which divide into branches, and anastomose together in the same manner as the tubes. Kölliker, who confirms Lent's observations, thinks it probable that a single cell may generate a tube in its whole length; at the same time a cell is sometimes constricted or incompletely divided into two, the more superficial of which becomes narrowed and lengthened into the dentinal tube.

With respect to the actual formation of the hard substance of the tooth, two views have been entertained; Kölliker conceiving it to proceed from the calcification of a soft matrix excreted from the dentinal cells and their thin prolongations already referred to; whereas Waldeyer, who denies the existence of a preformative membrane, maintains that the formation of the dentine consists in the conversion of a part of the protoplasm of the dentinal cells into a collagenous substance, which is subsequently calcified, while the remaining part of the cell protoplasm continues in the form of soft fibres to occupy the interior of the tube surrounded by the calcified substance. (Op. cit. p. 189.) When the cap of dentine is examined in the newly-formed state, besides the ordinary dentine, globules are commonly observed; but if diluted hydrochloric acid is added, the globules disappear. Hence Czermak concludes that earthy impregnation proceeds for a time in a globular form, and that the after-presence of globular dentine is the result of arrested development; perfect development leading to the filling up of the spaces between the globules, and to the production of a uniformly compact tissue.

The enamel appears in the form of prismatic fibres which, until the point was contested by Huxley, have been generally supposed to be produced by calcification of the cells of the enamel-membrane, with which they correspond in figure. An enamel fibre may be formed by a single cell growing in length, while its previously formed

portion becomes calcified, or by the union of a series of successively formed cells arranged vertically to the surface. During its formation the enamel is soft and chalky, and can easily be separated into its component prisms. Afterwards, the membranous portion of it is nearly all obliterated, and the nuclei entirely disappear, or, according to Tomes, elongate into a very fine central canal in each fibre. It is observed by Huxley, that if the pulp is treated with acetic acid, a voluminous, transparent membrane is raised from the whole surface in large folds, and that the ends of the enamel fibres are to be seen beneath it. The membrane is from $\frac{1}{7500}$th to $\frac{1}{1800}$ th of an inch in thickness; is clear, transparent, and exhibits little ridges bounding oval or quadrangular spaces; and is, according to him, continuous with the membrana præformativa. Huxley, therefore, considers that the enamel appears between the dentine and the preformative membrane, and that the enamel organ takes no part in its formation. Tomes confirms the observation of Huxley with regard to the separability of this apparent membrane by acetic acid; but, upon closer examination finds that it may be split in columns, which are, in conformity with his view of the structure of enamel, sheaths containing nuclei. Tomes, further, believes that these sheaths may be seen to pass through the membrane, which Huxley describes as limiting them superficially; and that, consequently, it is not as Huxley imagines the membrana præformativa. Waldeyer holds that the membrane described by Huxley between the enamel and the enamel organ is only a layer of the most recently formed enamel, as he finds it possible always to detect enamel cells with the ends partially calcified. He returns, therefore, to Schwann's original view, that the formation of the enamel columns is due to the direct calcification of the enamel cells. (Henle's Bericht, &c. for 1864, p. 81, and op. cit.)

Fig. 557.

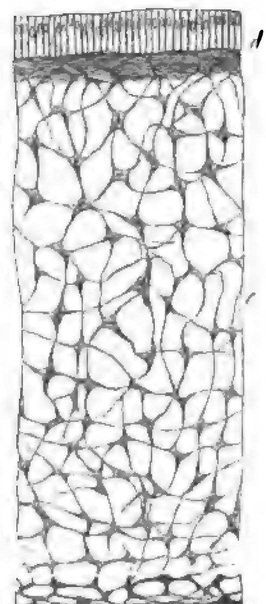


Fig. 557.—A SECTION THROUGH THE ENAMEL ORGAN AND DENTAL SAC FROM THE TOOTH OF A CHILD AT BIRTH (from Kölliker). $\frac{350}{1}$

a, outer dense layer of the dental sac; *b*, inner looser texture of the same with capillary bloodvessels and a somewhat denser layer towards the enamel organ; *c*, spongy substance; *d*, inner cells; and *e*, outer cellular layer of the enamel organ.

B, four cells of the enamel-membrane. $\frac{350}{1}$

The Cement appears to be formed simultaneously with the dentine of the fang by the periodontal membrane.

Eruption of the temporary teeth.—At the time of birth the crowns of the anterior milk-teeth, still enclosed in their sacs, are completed within the jaw, and their fangs begin to be formed. Their appearance through the gums follows a regular order, but the period at which each pair of teeth is cut varies within certain

limits. The eruption commences at the age of seven months, and is completed about the end of the second year. It begins with the central incisors

Fig. 558.

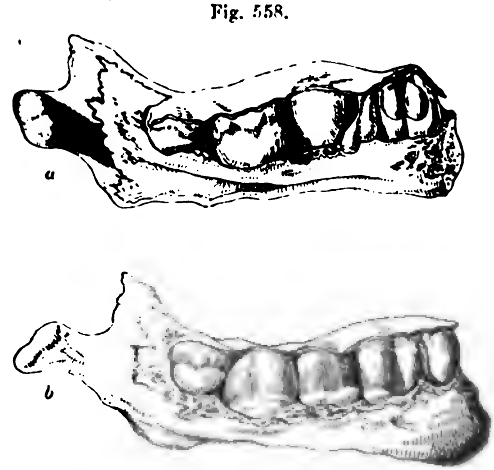


Fig. 558.—The Dental Sacs exposed in the Jaw of a Child at Birth.

a, the left half seen from the inner side; *b*, the right half seen from the outer side; part of the bone has been removed so as to expose the dental sacs as they lie below the gum; the lower figure shows the sacs of the milk teeth and the first permanent molar, exposed by removing the bone from the outside; the upper figure shows the same from the inside, together with the pediculated sacs of the permanent incisor and canine teeth adhering to the gum.

of the lower jaw, which are immediately followed by those of the upper jaw; and, as a general rule, each of the lower range of teeth rises through the gum before the corresponding tooth of the upper set. The following scheme indicates in months, the order and time of eruption of the milk-teeth.

MOLARS.	CANINES.	INCISORS.	CANINES.	MOLARS.
24 12	18	9 7 7 9	18	12 24

Before the teeth protrude through the gum, this undergoes some peculiar changes: its edge at first becomes dense and sharp, but as the tooth approaches it, the sharp edge disappears, the gum becomes rounded or tumid, and is of a purplish hue; the summit of the tooth is seen like a white spot or line through the vascular gum, and soon after rises through it. As the crown of the tooth advances to its ultimate position, the elongated fang becomes surrounded by a bony socket or alveolus. Before the eruption, the mucous membrane is studded with a number of small white bodies, which were described by Serres as glands (*dental glands*), and were supposed by him to secrete the tartar of the teeth. Meckel thought they were small abscesses, because no aperture could be detected in them. In a fœtus of six months, they were found by Sharpey to be small round pearl-like bodies situated in the corium of the mucous membrane, and having no aperture: they consist of small spherical capsules of various sizes, lined with a thick stratum of epithelium, the inner cells of which are flattened or scaly, like those lining the cheek, and are so numerous as almost to fill up the cavity. They are the prominences of the outer epithelial layer of the enamel organ, already referred to.

Development of the permanent teeth.—The preceding description of the structure of the dental sacs and pulps and of the mode of formation of the

several parts of a tooth, applies to the permanent as well as to the milk teeth.

The origin and progressive development of the sacs of the permanent teeth have still to be considered. There are six more permanent teeth in each jaw than there are milk teeth, and it is found that the sacs of the ten anterior permanent teeth, which succeed the ten milk teeth, have a different mode of origin from the six additional or superadded teeth, which are formed further back in the jaw.

Fig. 559.

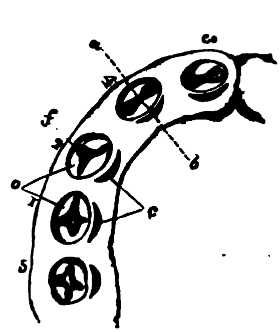


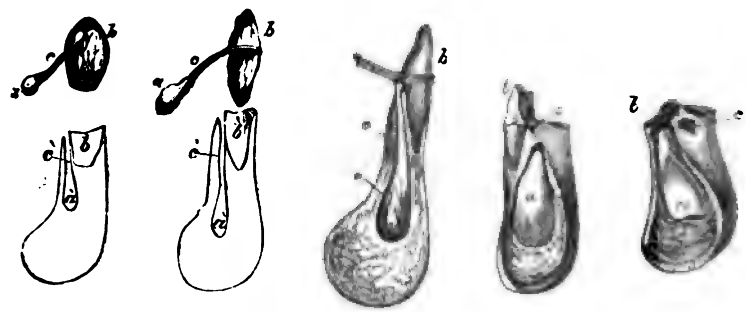
Fig. 559.—ENLARGED DIAGRAM OF THE DENTAL ARCH ON THE LEFT SIDE OF THE LOWER JAW OF A FŒTUS OF ABOUT FOURTEEN WEEKS (slightly altered from Goodsir).

f, the follicles of the five milk-teeth, supposed to be open, showing the dental papillæ within them, and *o*, the opercula on their borders; they are numbered from 1 to 5 in the order of their first appearance; *c*, to the inside of each is the lunated depression forming the commencement of the germ of the corresponding permanent tooth; *a b*, line of the section shown in fig. 551, 5.

The sacs and pulps of the ten *anterior permanent* teeth have their foundations laid before birth, behind those of the milk set. Recurring to the follicular stage of the temporary teeth, which is completed about the fourteenth week, it will be remembered that behind each milk follicle there is formed a small lunated recess, similar in form to an impression made by the nail. As already stated, the mucous membrane lining these recesses escapes the general adhesion of the lips and sides of the dental groove, so that when the latter closes they are converted into so many cavities, which are called by Goodsir, "*cavities of reserve.*" They are ten in number in each jaw, and are formed successively from before backwards. They ultimately form the sacs for the permanent incisor, canine, and bicuspid teeth. These cavities soon elongate and recede into the substance of the gum behind the milk follicles, above and behind in the upper jaw, below and behind in the lower. In the meantime, a papilla appears in the bottom of each, (that for the central incisor appearing first, at about the sixth month,) and one or more folds or opercula, as in the case of the temporary teeth, are developed from the sides of the cavity, and by their subsequent union, divide it into two portions, the lower portion containing the papilla, and now forming the dental sac and pulp of the permanent tooth, and the upper and narrower portion being gradually obliterated in the same manner as the primitive groove was closed over the milk-sacs. When these changes have taken place, the permanent sac adheres to the back of that for the temporary tooth. Both of them continue then to grow rapidly, and after a time it is found that the bony socket not only forms a cell for the reception of the milk sac, but also a small posterior recess or niche for the permanent sac, with which the recess keeps pace in its growth. Confining our description now, for convenience, to the lower jaw only, it is found that at length the permanent sac so far recedes in the bone as to be lodged in a special osseous cavity at some distance below and behind the milk tooth, the two being completely separated from each other by a bony partition. In descending into

the jaw, the permanent sac acquires at first a pear-shape, and is then connected with the gum by a solid membranous pedicle. The recess in the jaw has a similar form, drawn out into a long canal for the pedicle, which opens

Fig. 560.



I. II. III. IV. V.

Fig. 560.—Sketches showing the Relations of the Temporary and Permanent Dental Sacs and Teeth (after Blake, with some additions).

The lower parts of the three first figures, which are somewhat enlarged, represent sections of the lower jaw through the alveolus of a temporary incisor tooth : *a*, indicates the sac of the permanent tooth ; *c*, its pedicle ; *b*, the sac of the milk tooth or the milk tooth itself; *a'*, *b'*, indicate the alveolar recesses in which the permanent and temporary teeth are lodged, and *c*, the canal by which that of the former leads to the surface of the bone behind the alveolus of the temporary tooth. The fourth and fifth figures, which are nearly of the natural size, show the same relations in a more advanced stage, in IV, previous to the change of teeth, in V, when the milk-tooth has fallen out and the permanent tooth begins to rise in the jaw; *c*, the orifice of the bony canal leading to the place of the permanent tooth.

on the edge of the jaw, by an aperture behind the corresponding milk tooth. The permanent tooth is thus separated from the socket of the milk tooth by a bony partition, against which, as well as against the root of the milk tooth just above it, it presses in its rise through the gum, so that these parts are in a greater or less extent absorbed. When this has proceeded far enough, the milk tooth becomes loosened, falls out or is removed, and the permanent tooth takes its place. The absorption of the dental substance commences at or near the ends of the fangs, and proceeds upwards until nothing but the crown remains. The cement is first attacked, and then the dentine : but the process is similar in the two tissues. The change is not produced merely by pressure, but through the agency of a special cellular structure developed at the time, and applied to the surface of the tooth. Hollows or indentations occur upon the latter, giving it a festooned appearance : and it frequently happens that the dental tissues are deposited, absorbed, and redeposited alternately in the same tooth (Tomes). The milk teeth and the permanent teeth are said by Serres to be supplied by two different arteries, the obliteration of the one belonging to the temporary teeth being regarded by him as the cause of their destruction ; but of this there is no sufficient proof.

The six *posterior* (or "*superadded*") *permanent* teeth, that is, the three permanent molars on each side, do not come in the place of other teeth. They arise from successive extensions of the dental groove carried backwards in the jaw, posterior to the milk teeth, and named by Goodsir "*posterior cavities of reserve.*"

During the general adhesion of the dental groove occurring at the fifteenth week, the part posterior to the last temporary molar follicle continues unobliterated, and thus forms a cavity of reserve, in the fundus of which a papilla ultimately appears, and forms the rudiment of the first permanent molar tooth : this takes place very early, viz., at the sixteenth week. The deepest part of this cavity is next converted by adhesion into a sac, which encloses the papilla, whilst its upper portion elongates backwards so as to form another cavity of reserve, in which, at the seventh month after birth, the papilla for the second molar tooth appears. After a long interval, during which the sac of the first permanent molar and its contained tooth have acquired great size, and that of the second molar has also advanced considerably in development, the same changes once more occur, and give rise to the sac and papilla of the wisdom tooth, the rudiments of which are visible at the sixth year. The subsequent development of the permanent molar teeth takes place from these sacs just like that of the other teeth.

Calcification begins first in the anterior permanent molar teeth. Its order and periods may be thus stated for the upper jaw, the lower being a little earlier. First molar, five or six months after birth ; central incisor, a little later ; lateral incisor and canine, eight or nine months ; two bicuspids, two years or more ; second molar, five or six years ; third molar, or wisdom tooth, about twelve years.

Fig. 561.

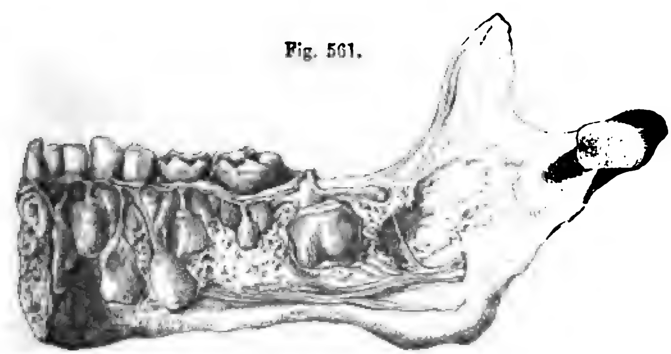


Fig. 561.—Part of the Lower Jaw of a Child of Three or Four Years Old, showing the Relations of the Temporary and Permanent Teeth.

The specimen contains all the milk teeth of the right side, together with the incisors of the left ; the inner plate of the jaw has been removed, so as to expose the sacs of all the permanent teeth of the right side, except the eighth or wisdom tooth, which is not yet formed. The large sac near the ramus of the jaw is that of the first permanent molar, and above and behind it is the commencing rudiment of the second molar.

Eruption of the permanent teeth.—The time at which this occurs in regard to each pair of teeth in the lower jaw is exhibited in the subjoined table. The corresponding teeth of the upper jaw appear somewhat later.

Molar, first	6	years.
Incisors, central	7	,,
,, lateral	8	,,
Bicuspids, anterior	9	,,
,, posterior	10	,,
Canines	11 to 12	,,
Molars, second	12 to 13	,,
,, third (or wisdom)	17 to 25	,,

It is just before the shedding of the temporary incisors, *i. e.*, about the sixth year, that there is the greatest number of teeth in the jaws. At that period there are all the milk teeth, and all the permanent set except the wisdom teeth, making forty-eight.

Fig. 562.

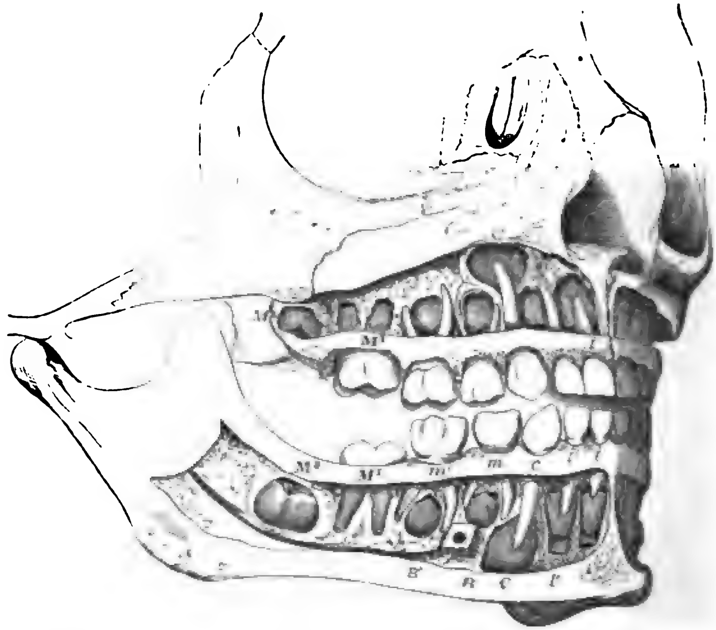


Fig. 562.—THE TEETH OF A CHILD OF SIX YEARS, WITH THE CALCIFIED PARTS OF THE PERMANENT TEETH EXPOSED (after Henle and from nature).

The whole of the teeth of the right side are shown, together with the three front teeth of the left side: in the upper and lower jaws the teeth are indicated as follows, viz.:— 1, *milk teeth* — *i*, inner or first incisor; *i'*, outer or second incisor; *c*, canine; *m*, first molar; *m'*, second molar. 2, *permanent teeth* — I, inner or first incisor; I', outer or second incisor; C, canine; B, first bicuspid; B', second bicuspid; M^1, the first molar, which has passed through the gums; M^2, the second molar, which has not yet risen above the gums: the third molar is not yet formed.

During the growth of the teeth the jaw increases in depth and length, and undergoes changes in form. In the child it is shallow, but it becomes much deeper in the adult. In the young subject the alveolar arch describes almost the segment of a circle; but in the adult the curve is semi-elliptical. The increase which takes place in the length of the jaw arises from a growth behind the position of the milk teeth, so as to provide room for the three additional teeth on each side belonging to the permanent set. At certain periods in the growth of the jaws there is not sufficient room in the alveolar arch for the growing sacs of the permanent molars; and hence those parts are found at certain stages of their development to be enclosed in the base of the coronoid process of the lower jaw, and in the maxillary tuberosity in the upper jaw, but they afterwards successively assume their ultimate position as the bone increases in length. The space taken up by the ten

anterior permanent teeth very nearly corresponds with that which had been occupied by the ten milk-teeth; the difference in width between the incisors of the two sets being compensated for by the smallness of the bicuspids in comparison with the milk molars to which they succeed. Lastly, the angle formed by the ramus and body of the lower jaw differs at different ages; thus it is obtuse in the infant, approaches nearer to a right angle in the adult, and again becomes somewhat obtuse in old age. (See p. 52.)

Relation of the blood-vessels and nerves to the tooth.—There is no evidence that the blood-vessels send branches into the hard substance. The red stain sometimes observed in the teeth, after death by asphyxia, and the red spots occasionally found in the dentine, are due to the imbibition of blood effused on the surface of the pulp. The dentine formed in young animals fed upon madder is tinged with that colouring matter, but this does not appear to take place when the growth of the tooth is completed. Nevertheless the tubules of the dentine may serve to convey through its substance nutrient fluid poured out by the blood-vessels of the pulp. The teeth are sometimes stained yellow in jaundice.

According to Czermak the primitive nerve tubules run into the tooth-pulp in bundles, which are large towards the centre, and small at the periphery. They lose themselves in a plexus at the surface of the pulp. Czermak states that the fibres often divide, but that he has not seen loops frequently, and he is doubtful as to the precise mode of their termination.

THE TONGUE.

The *tongue* is a muscular organ covered with mucous membrane. By its muscular structure it takes part in the processes of mastication and deglutition, and in the articulation of speech, while its mucous membrane is endowed with common sensibility and is the seat of the sense of taste. The tongue occupies the concavity of the arch of the lower jaw: posteriorly it is connected with the hyoid bone, and the back part of its dorsum forms the floor of the arch of the fauces; inferiorly it receives from base to apex the fibres of the genio-glossus muscle, and through the medium of that muscle is attached to the lower jaw.

A.—Mucous Membrane.—On the *under surface* of the tongue the mucous membrane is smooth and thin. It forms a fold in the middle line, called the *frænum linguæ*, placed in front of the anterior border of the genio-glossi muscles. On each side below, as the mucous membrane passes from the tongue to the inner surface of the gums, it is reflected over the sublingual gland. Not far from the line continued forwards from the frænum, the ranine vein may be distinctly seen through the mucous membrane, and close to it lies the ranine artery. Further outwards is an elevated line with a fimbriated margin directed outwards, which extends to the tip. The ducts of the right and left submaxillary glands end by papillary orifices placed close together, one on each side of the frænum; and further back, in the groove between the sides of the tongue and the lower jaw, are found the orifices of the several ducts belonging to the sublingual glands.

The *upper surface* or *dorsum* of the tongue is convex in its general outline, and is marked along the middle in its whole length by a slight furrow called the *raphe*, which indicates its bilateral symmetry. About half an inch from the base of the tongue, the raphe often terminates in a depression, closed at the bottom, which is called the *foramen cæcum* (Morgagni), and in which several mucous *glands* and follicles open. Three folds, named the glosso-epiglottic folds or frænula, of which the middle one is the largest (frænum epiglottidis), pass backwards from the base of the tongue to the epiglottis. The upper surface of the tongue is completely covered with

numerous projections or eminences named *papillæ*. They are found also upon the tip and free borders, where, however, they gradually become smaller, and disappear towards its under surface. These papillæ are distinguished into three orders, varying both in size and form.

Fig. 563.

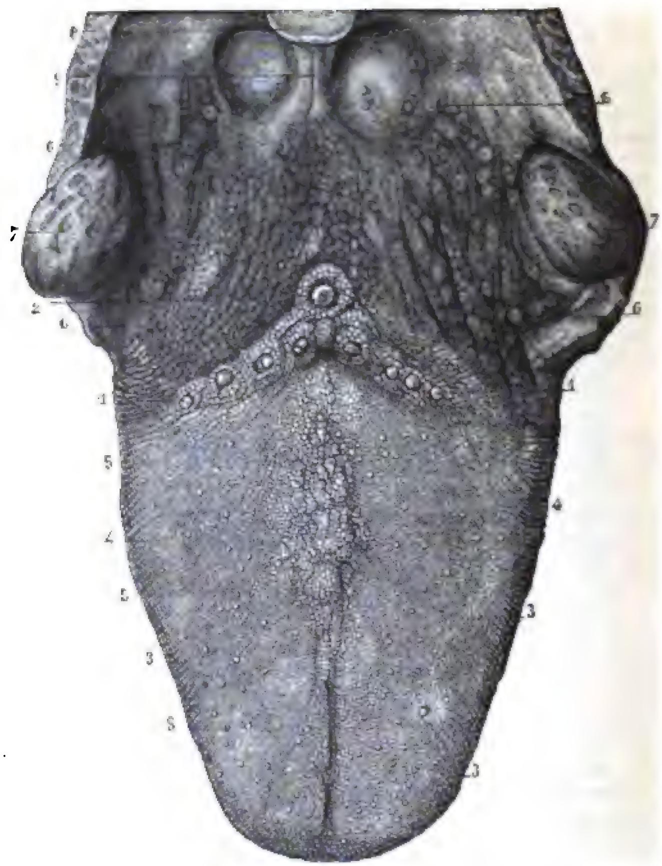


Fig. 563.—Papillar Surface of the Tongue, with the Fauces and Tonsils (from Sappey).

1, 2, circumvallate papillæ; in front of 2, the foramen cæcum; 3, fungiform papillæ; 4, filiform and conical papillæ; 5, transverse and oblique rugae; 6, mucous glands at the base of the tongue and in the fauces; 7, tonsils; 8, part of the epiglottis; 9, median glosso-epiglottidean fold or frænum epiglottidis.

The *large* or *circumvallate* papillæ, from seven to twelve in number, are found on the back part of the tongue, arranged in two rows, which run obliquely backwards and inwards, and meet towards the foramen cæcum, like the arms of the letter V. They are situated in cup-like cavities or depressions of the mucous membrane, and have the shape of an inverted cone, of which the apex is attached to the bottom of the cavity, and the broad flattened base appears on the surface. They are therefore surrounded by a

circular furrow or trench, around which again is an annular elevation of the mucous membrane, covered with the smaller papillæ. The exposed surface of the papillæ vallatæ is beset with numerous smaller papillæ or filaments;

Fig. 564.

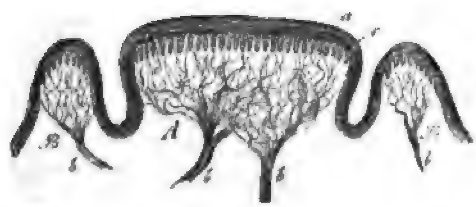


Fig. 564.—Vertical Section of the Circumvallate Papillæ (from Kölliker). $\frac{10}{1}$

A, the papilla; B, the surrounding wall; *a*, the epithelial covering; *b*, the nerves of the papilla and wall spreading towards the surface; *c*, the secondary papillæ.

and in some of them there is found a central depression, into which mucous follicles open.

The *middle-sized* or *fungiform* papillæ, more numerous than the last, are small rounded eminences scattered over the middle and fore part of the dorsum of the tongue; but they are found in great numbers and closer

Fig. 565.

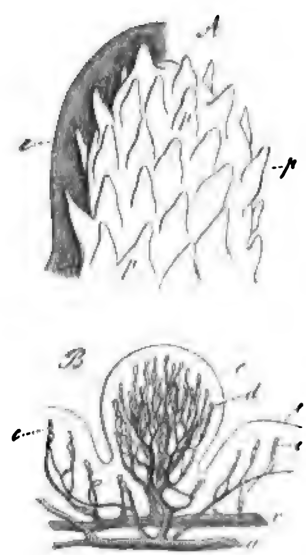


Fig. 565.—Surface and Section of the Fungiform Papillæ (from Kölliker after Todd and Bowman).

A, the surface of a fungiform papilla partially denuded of its epithelium, $\frac{35}{1}$; *p*, secondary papillæ; *e*, epithelium.

B, section of a fungiform papilla with the bloodvessels injected. *a*, artery; *v*, vein; *c*, capillary loops of simple papillæ in the neighbouring structure of the tongue; *d*, capillary loops of the secondary papillæ; *e*, epithelium.

together at the apex and upon the borders. They are easily distinguished in the living tongue by their deeper red colour. They are narrow at their point of attachment, but are gradually enlarged towards their free extremities, which are blunt and rounded, and are covered with smaller filamentous appendages or papillæ.

The *smallest papillæ, conical* and *filiform*, are the most numerous of all. They are minute, conical, tapering, or cylindrical processes, which are densely packed over the greater part of the dorsum of the tongue, but towards the base gradually disappear. They are arranged in lines, which correspond at first with the oblique direction of the two ridges of the papillæ vallatæ, but gradually become transverse towards the tip of the tongue. At the sides they are longer and more filiform, and arranged in parallel rows, perpendicular to the border of the tongue.

Considerable variety occurs in the appearance of the papillæ on the tongues of different persons. Thus occasionally instances occur in which the tongue has a quite smooth appearance, and others are seen in which numbers of the filiform papillæ are elongated into the appearance of short brown hairs, as shown in Fig. 566.

When examined microscopically in sections, all the kinds of papillæ now described are observed to be bearers of closely-set secondary papillæ. The secondary papillæ are the structures which correspond with the papillæ of the general integument, and are occupied each by a long loop of capillary bloodvessel. Simple papillæ of the same description are likewise interspersed between the three large kinds, and are found on the back part of

Fig. 566.

Fig. 566.—Two Filiform Papillæ, one with Epithelium, the other without (from Kölliker, after Todd and Bowman). $\frac{25}{1}$

p, the substance of the papillæ dividing at their upper extremities into secondary papillæ; *a*, artery, and *v*, vein, dividing into capillary loops; *e*, epithelial covering, laminated between the papillæ, but extended into hair-like processes *f*, from the extremities of the secondary papillæ.

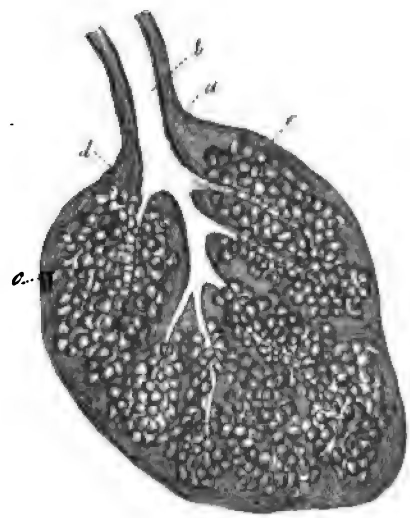
the tongue, behind the circumvallate range, as well as covering the under surface of the tongue and the rest of the mucous membrane of the mouth. The epithelium covering the tongue, like that of the mouth generally, is of the squamous kind. It is of considerable thickness, and the simple papillæ, together with the secondary papillæ surmounting those of the circumvallate and fungiform kinds, are concealed beneath it, or nearly so. But the secondary papillæ, borne by those of the filiform kind, are peculiar both in containing a number of elastic fibres, which give them greater firmness, and in the character of their epithelial covering, which is dense and imbricated, and which forms a separate process over each, greater in length than the papilla which it covers. Over some of the filiform papillæ these processes form a pencil of fine fibres; and on others they approach closely in character and structure to hairs. The papillæ are undoubtedly the parts chiefly concerned in the special sense of taste; but they also possess, in a very acute degree, common tactile sensibility; and the filiform papillæ, armed with their denser epithelial covering, serve a mechanical use, in the action of the tongue upon the food, as is well illustrated by the more developed form which these papillæ attain in many carnivorous animals. The papillary surface of the tongue is supplied abundantly with nerves. It is difficult to trace the nerve fibres in the papillæ filiformes, owing to the presence of elastic filaments. In the papillæ fungiformes the nerves are larger and more numerous, and form a plexus with brush-like branches: but they are still more abundant, and of greater size in the papillæ circumvallatæ.

Little that is satisfactory is known of the mode of termination of the

nerve filaments in the human tongue. It is still a matter of doubt whether they enter the secondary papillæ surmounting the filiform set, the density of the tissue rendering the investigation peculiarly difficult in these. In the frog's tongue, Billroth and Axel Key believe that they have traced continuity of nerve filaments with structures in the epithelium; and according to Axel Key, the arrangement is very similar to that of the olfactory cells —viz., rodlike bodies placed between the epithelial cells and continuous by their deep extremities with varicose fibres. (Billroth in Müller's Archiv, 1858, p. 159; Axel Key in Reichert's Archiv, 1861, p. 329.)

Glands.—The mucous membrane of the tongue is provided with numerous follicles and glands. The follicles, simple and compound, are scattered over the surface; but the rounded conglomerate glands, called *lingual glands*, are collected about the posterior part of the dorsum of the tongue, near the papillæ vallatæ and foramen cæcum, into which last the ducts of several of these glands open. Other small glands are found also beneath the mucous membrane of the borders of the tongue. There is, in particular, a small group of these glands on the under surface of the tongue near the apex. They are there aggregated into a small oblong mass, out of which several ducts proceed and open separately on the mucous membrane. (Blandin, in Archives gén. de Médecine, 1823; Nuhn, Ueber eine noch nicht näher beschriebene Zungendrüse, Mannheim, 1845.)

Fig. 567.
A.



B.

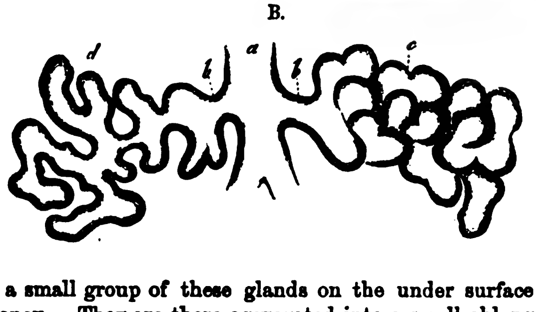


Fig. 567.—Racemose Mucous Gland, from the Floor of the Mouth (from Kölliker).

A, the entire gland as seen in section; $\frac{50}{1}$ *a*, covering of connective tissue; *b*, excretory duct; *c*, glandular vesicles; *d*, duct of one of the lobules.

B, diagram of one of the lobules, more highly magnified; *a*, excretory duct of the lobule; *b*, secondary branch; *c*, the glandular vesicles as they lie together in the gland; *d*, the same separated, showing their connection as a glandular tube.

B.—Muscular Substance.—The substance of the tongue is chiefly composed of muscular fibres, running in different but determinate directions;—hence the variety and regularity of its movements, and its numerous changes of form. Many of the contractile fibres of the tongue belong to muscles

which enter at its base and under surface, and attach it to other parts: these are called the *extrinsic muscles* of the tongue, and have been elsewhere described (pp. 185—186). Other bands of fibres which constitute the *intrinsic* or proper muscles, and are placed entirely within the substance of the organ, will be here more particularly noticed. They are as follow :—

The *lingualis superficialis* (*noto-glossus*, Zaglas), consisting mainly of longitudinal fibres, is placed on the upper surface of the tongue, immediately beneath the mucous membrane, and is traceable from the apex of the organ backwards to the hyoid bone. The individual fibres do not run the whole of this distance, but are attached at intervals to the submucous and glandular tissues. The entire layer becomes thinner towards the base of the tongue, near which it is overlapped at the sides by a thin plane of oblique or nearly transverse fibres derived from the palato-glossus and hyo-glossus muscles. According to Zaglas, the fibres of this muscle are directed forwards and outwards.

The *lingualis inferior* (lingualis muscle of Douglas, Albinus, &c.) consists of a rounded muscular band, extending along the under surface of the tongue from base to apex, and lying outside the genio-hyo-glossus between that muscle and the hyo-glossus. Posteriorly, some of its fibres are lost in the substance of the tongue, and others reach the hyoid bone. In front,

Fig. 568.

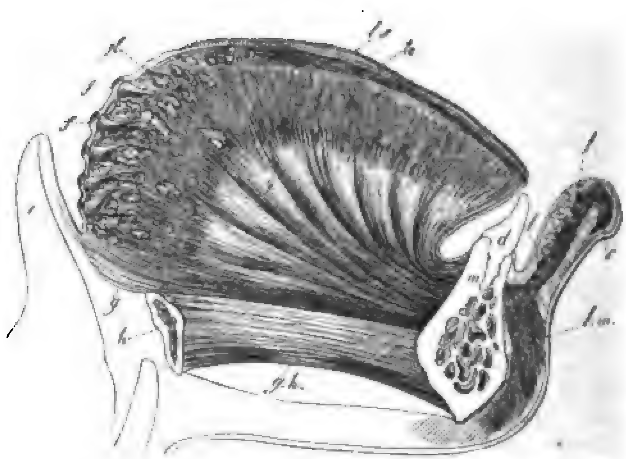


Fig. 568.—Longitudinal Vertical Section of the Tongue, Lip, &c. (from Kölliker and Arnold).

m, symphysis of the lower jaw ; *d*, incisor tooth ; *h*, hyoid bone ; *g h*, genio-hyoid muscle ; *g*, genio-hyo-glossus spreading into the whole extent of the tongue ; *tr*, transverse muscle ; *l s*, superior longitudinal muscle ; *g l*, lingual glands ; *f*, lingual follicles ; *e*, epiglottis ; *l*, section of the lip and labial glands ; *o*, cut fibres of the orbicularis oris ; *l m*, levator menti.

having first been joined, at the anterior border of the hyo-glossus muscle, by fibres from the stylo-glossus, it is prolonged beneath the border of the tongue as far as its point.

The *transverse* muscular fibres of the tongue form together with the intermixed fat a considerable part of its substance. They are found in the in-

terval between the upper and lower longitudinal muscles, and they are interwoven extensively with the other muscular fibres. Passing outwards from the median plane, where they take origin from a fibrous septum, they reach the dorsum and borders of the tongue. In proceeding outwards, they separate, and the superior fibres incline upwards, forming a series of curves with the concavity turned upwards. The fibres of the palato-glossus muscle are found by Zaglas and Henle to be continuous with fibres of the transverse set.

Fig. 569.

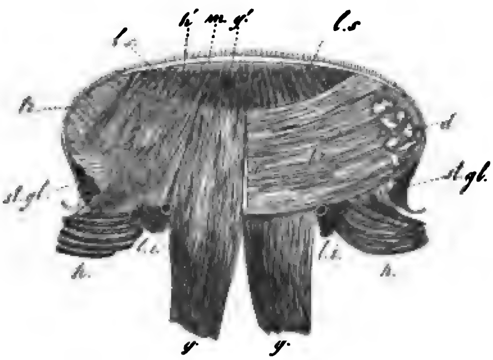


Fig. 569. — Transverse Vertical Section of the Tongue in front of the Papillæ Vallatæ, seen from before (from Kölliker).

g, the genio-hyo-glossi muscles; *g'*, the vertical fibres of the right side traced upwards to the surface; *li*, inferior longitudinal muscle with the divided ranine artery; *tr*, transverse muscle, entire on one side, but partially removed on the other, where the other muscles pass through it; *c*, septum linguæ; *h*, hyoglossus; *h g l*, its fibres spreading upwards almost vertically outside the genio-hyo-glossus; *h'*, vertical fibres reaching the surface; *l s*, divided plates of the fibres of the superior longitudinal muscle between the vertical fibres; *s t*, *g l*, stylo-glossus; *d* glands near the border of the tongue.

Vertical fibres (musculus perpendicularis externus of Zaglas), decussating with the transverse fibres and the insertions of the genio-glossus, form a set of curves in each half of the tongue with their concavity upwards, and extending downwards and outwards from the dorsum to the under surface of the border, so that those which are outermost are shortest. (Zaglas, "On the Muscular Structure of the Tongue," in Goodsir's Annals, I. p. 1.)

Examined in transverse sections, the muscular fibres of the tongue are seen to be arranged so as to render the substance divisible into an outer part or *cortex* and a softer internal *medulla*. The fibres of the cortex are principally longitudinal, derived superiorly from the lingualis superior, further outwards from the hyo-glossus, on the side from the stylo-glossus, and beneath this from the lingualis inferior. They sheathe the medullary part on all sides except inferiorly, where the genio-glossi muscles enter it between the inferior linguales. In the medullary part are found, imbedded in fat, the decussating fibres of the transverse muscle passing across, the genio-glossi radiating upwards and outwards, and the vertical muscles arching downwards and outwards. In addition to the movements which may be given to the tongue by the extrinsic muscles, this organ is capable of being curved upwards, downwards, or laterally by its cortical fibres, it is flattened by the vertical fibres, and its margins are again drawn together by the transverse.

The septum of the tongue is a thin fibrous partition which extends forwards from the hyoid bone to the tip, and divides one half of the medullary part of the tongue from the other, but does not penetrate into the cortex. It corresponds with the fusiform fibro-cartilage, found in the middle of the tongue of the dog, near its under surface.

The *arteries* of the tongue are derived from the lingualis, with some small branches from the facial and ascending pharyngeal. With these the veins for the most part correspond. (See pp. 348 and 456.)

Fig. 570.

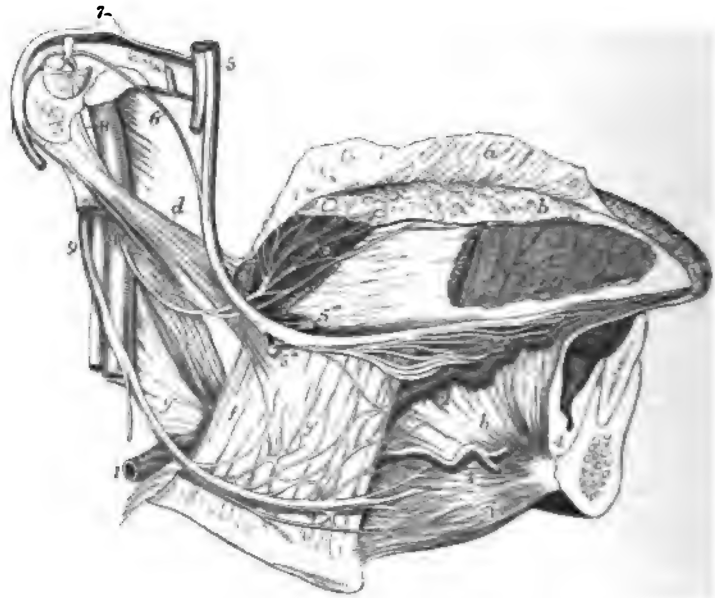


Fig. 570.—Lateral View of the Nerves and Blood-vessels of the Tongue (from Hirschfeld and Leveillé).

The lower jaw has been divided near the symphysis, and the right half removed; the hyoid bone is entire, and the extrinsic muscles of the tongue are preserved on the right side. *a*, the epithelial covering of the tongue partially raised; *b*, the papillar surface of the mucous membrane exposed; *c*, the same near the papillæ vallatæ; *d*, placed on the superior constrictor of the pharynx, points to the stylo-glossus muscle; *e*, stylo-pharyngeus muscle, passing within the middle constrictor; *f*, hyo-glossus; *g*, middle constrictor of the pharynx; *h*, genio-hyo-glossus; *i*, genio-hyoideus; 1, trunk of the lingual artery; 2, ranine artery; 3, sublingual branch; 4, its terminal branches; 5, trunk of the gustatory nerve; 5′, distribution of its terminal twigs in the mucous membrane of the fore part of the tongue; 5″, submaxillary ganglion; 5‴, another small ganglion, connected with the gustatory nerve; 6, chorda tympani nerve, passing from the facial nerve 7, to the trunk of the gustatory; 8, trunk of the glosso-pharyngeal, receiving a twig of communication from the facial; 8′, its distribution near the papillæ vallatæ; 9, hypoglossal nerve; 9′, its twigs to the hyo-glossus muscle and union with the gustatory; further forward are seen its terminal branches to the muscular substance of the tongue.

The *nerves* of the tongue (exclusive of branches from the sympathetic nerves) are three: viz. the lingual or *gustatory* branch of the *fifth* pair, which supplies the papillæ and mucous membrane of the fore part and sides of the tongue to the extent of about two-thirds of its surface; the lingual branch of the *glosso-pharyngeal*, which sends filaments to the mucous membrane at the base of the tongue, and especially to the papillæ vallatæ; and, lastly, the *hypoglossal* nerve, which is distributed to the muscles. (See the description of these nerves.) Remak and Kölliker have discovered microscopic ganglia upon the expansion of the glosso-pharyngeal nerve, and in the sheep and calf upon the gustatory division of the fifth. Remak thought that they had some relation to the glands, but Kölliker finds them on branches not connected with those organs.

THE PALATE.

The roof of the mouth is formed by the palate, which consists of two portions; the fore part being named the hard palate, and the back part, the soft palate.

The osseous framework of the *hard* palate, already described with the bones of the face, is covered by the periosteum, and by the lining membrane of the mouth, which adhere intimately together. The mucous membrane, which is continuous with that of the gums, is thick, dense, rather pale, and much corrugated, especially in front and at the sides; but is smoother, thinner, and of a deeper colour behind. Along the middle line is a ridge or raphe, ending in front in a small eminence, which corresponds with the lower opening of the anterior palatine canal, and receives the terminal filaments of the naso-palatine and anterior palatine nerves. The membrane of the hard palate is provided with many muciparous glands, which form a continuous layer between the membrane and the bone, and it is covered with a squamous epithelium.

The *soft* palate (velum pendulum palati), is formed of a doubling of mucous membrane inclosing muscular fibres and numerous glands. It constitutes an incomplete and movable partition between the mouth and the pharynx, continued from the posterior border of the hard palate, obliquely downwards and backwards. Its form and its inferior connections, bounding the isthmus of the fauces, have been already described, together with the muscles which enter into its composition, at p. 189.

The anterior or under surface of the velum, which is visible in the mouth, is concave. The mucous membrane, continuous with that of the hard palate, is thinner and darker than it, and is covered like it with scaly epithelium. The median ridge or raphe, which is continued backwards from the hard palate to the base of the uvula, indicates the original separation of the velum into two lateral halves.

The posterior surface of the soft palate, slightly convex or arched, is continuous above with the floor of the posterior nares. It is slightly elevated along the middle line, opposite to the uvula. The greater portion of its mucous membrane, as well as that of the free margin of the velum, is covered with a squamous epithelium; but quite at its upper portion, near the orifice of the Eustachian tube, the epithelium is columnar and ciliated.

On both surfaces of the velum are found numerous small glands, called the *palatine* glands. They particularly abound on the upper surface, where they form quite a glandular layer; they are also very abundant in the uvula.

THE TONSILS.

The *tonsils* (tonsillæ, amygdalæ) are two prominent bodies, which occupy the recesses formed, one on each side of the fauces, between the anterior and posterior palatine arches and the pillars of the fauces.

They are usually about six lines in length, and four in width and thickness; but they vary much in size in different individuals.

The outer side of the tonsil is connected with the inner surface of the superior constrictor of the pharynx, and approaches very near to the internal carotid artery. Considered in relation to the surface of the neck, the tonsil corresponds to the angle of the lower jaw, where it may be felt beneath the skin when it is enlarged. Its inner surface, projecting into the fauces

between the palatine arches, presents from twelve to fifteen orifices, which give it a perforated appearance. These orifices lead into recesses in the substance of the tonsil, from which other and smaller orifices conduct still deeper into numerous follicles. These follicles are lined by the epithelium and papillary mucous membrane of the throat, and have thick walls formed by a layer of closed capsules imbedded in the submucous tissue. The capsules, which may be compared to those of Peyer's glands of the intestine, besides having a mesh-work of capillary blood vessels and delicate trabecular tissue within them, are filled with consistent greyish substance, containing cells and free nuclei, but without the characters of mucus. A substance having the same microscopic elements is found in the cavity of the follicle, but here it is liable to be mixed with mucus supplied by true mucous glands, the ducts of which pass into the follicle. The function of the tonsils is as little known as that of the other glands formed of closed capsules which are found in the mucous membrane of the alimentary canal.

Fig. 571.

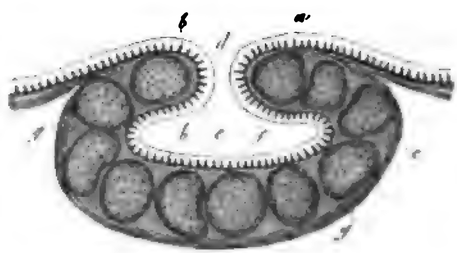


Fig. 571.—Section of a Follicular Gland from the Root of the Tongue (from Kölliker). $\frac{20}{1}$

a, epithelial lining; *b*, papillæ of the mucous membrane; *c*, outer surface of the capsule, formed of connective tissue; *d*, outlet, and *e*, cavity of the capsule; *g*, follicles in the substance of the capsular wall.

Follicular recesses, surrounded by closed capsules, like the recesses and capsules of the tonsils, are also found at the root of the tongue, where they form a layer extending from the papillæ vallatæ to the epiglottis, and from one tonsil to the other, lying immediately beneath the mucous membrane and above the mucous glands, many of whose ducts they receive.

The tonsils receive a very large supply of blood from various sources, viz. from the tonsillar and palatine branches of the facial artery, and from the descending palatine, the ascending pharyngeal and the dorsalis linguæ. From these arteries, fine branches and capillaries are distributed abundantly to the walls of the capsules and to the papillæ of the mucous membrane lining the follicles. The *veins* are numerous, and enter the tonsillar plexus on its outer side. The nerves come from the glosso-pharyngeal nerve, and from the fifth pair.

THE SALIVARY GLANDS.

The saliva, which is poured into the mouth, and there mixed with the food during mastication, is secreted by three pairs of glands, named from their respective situations, *parotid*, *submaxillary*, and *sublingual*. Agreeing in their general physical characters and minute structure, these glands differ in their size, form, and position.

The Parotid Gland.

The *parotid* is the largest of the three salivary glands. It lies on the side of the face, in front of the ear, and extends deeply into the space behind the ramus of the lower jaw. Its weight varies from five to eight drachms.

Its outer surface is convex and lobulated, and is covered by the skin and fascia, and partially by the platysma muscle. It is bounded above by the zygoma, below by a line drawn backwards from the lower border of the jaw to the sterno-mastoid muscle, and behind by the external meatus of the ear, the mastoid process, and sterno-mastoid muscle. Its anterior border, which lies over the ramus of the lower jaw, is less distinctly defined, and stretches forwards to a variable extent on the masseter muscle. It is from this anterior border of the gland that the excretory duct passes off; and there is

Fig. 572.

Fig. 572.—Sketch of a Superficial Dissection of the Face, showing the Position of the Parotid and Submaxillary Glands.

p, the larger part of the parotid gland; *p'*, the small part, which lies alongside the duct on the masseter muscle; *d*, the duct of Stenson before it perforates the buccinator muscle; *a*, transverse facial artery; *n*, *n*, branches of the facial nerve emerging from below the gland; *f*, the facial artery passing out of a groove in the submaxillary gland and ascending on the face; *s m*, superficial larger portion of the submaxillary gland lying over the posterior part of the mylo-hyoid muscle.

frequently found in connection with the duct, and lying upon the masseter muscle, a small process or a separated portion of the gland, which is called *glandula socia* (*socia parotidis*). On trying to raise the deeper part of the parotid gland from its position, it is found to extend far inwards, between the mastoid process and the ramus of the jaw, towards the base of the skull, and to be intimately connected with several deep-seated parts. Thus, above, it reaches into and occupies the posterior part of the glenoid cavity; behind and below, it touches the digastric muscle, and rests on the styloid

process and styloid muscles; and, in front, under cover of the ramus of the jaw, it advances a certain distance between the external and internal pterygoid muscles.

The internal carotid artery and internal jugular vein are close to the deep surface of the gland. The external carotid artery, accompanied by the temporal and internal maxillary veins, passes through the parotid gland; and in that situation arise the temporal and internal maxillary arteries, as also the auricular and transverse facial branches of the temporal. The gland is also traversed by the facial nerve, which divides into branches within its substance, and it is pierced by branches of the great auricular nerve.

The *parotid duct*, named also *Stenson's duct* (d. Stenonianus), appears at the anterior border of the gland, about one finger's breadth below the zygoma, and runs forwards over the masseter muscle, accompanied by the socia parotidis, when that accessory portion of the gland exists, and receiving its ducts. At the anterior border of the masseter, the duct turns inwards through the fat of the cheek and pierces the buccinator muscle; and then, after running for a short distance obliquely forwards beneath the mucous membrane, opens upon the inner surface of the cheek, by a small orifice opposite the crown of the second molar tooth of the upper jaw. Its direction across the face may be indicated by a line drawn from the lower margin of the concha of the ear to a point midway between the red margin of the lip and the ala of the nose. The length of the Stenonian duct is about two inches and a half, and its thickness about one line and a half. At the place where it perforates the buccinator, its canal is as large as a crow-quill, but at its orifice it is smaller than in any other part, and will only admit a very fine probe. The duct is surrounded by areolar tissue, and consists of an external, dense, and thick fibrous coat, in which contractile fibres are described, and of an internal mucous tunic, which is continuous with that of the mouth, but which is covered, from the orifice of the duct as far as to the smallest branches, with a columnar epithelium.

The parotid gland belongs to the class of compound racemose glands, and consists of numerous flattened lobes, held together by the ducts and vessels, and by a dense areolar web, which is continuous with the fascia upon its outer surface; but the gland has no special or proper coat. The lobes are again divided into lobules, each of which consists of the branched terminations of the duct, and of vessels, nerves, and fine areolar tissue. The ducts terminate in closed vesicular extremities, about $\frac{1}{300}$th of an inch or more in diameter, which are lined with epithelium, and have capillary vessels ramifying upon them.

The vessels of the parotid gland enter and leave it at numerous points. The arteries are derived directly from the external carotid, and from those of its branches which pass through or near the gland. The veins correspond. The absorbents join the deep and superficial set in the neck; and there are often one or more lymphatic glands imbedded in the substance of the parotid. The nerves come from the sympathetic (carotid plexus), and also, it is said, from the facial and the superficial temporal and great auricular nerves.

An instance is recorded by Gruber of a remarkable displacement of the parotid on one side; the whole gland being situated on the masseter muscle as if it were an enlarged socia parotidis. (Virchow's Archiv, xxxii., p. 328.)

The Submaxillary Gland.

The *submaxillary gland*, the next in size to the parotid gland, is of a spheroidal form, and weighs about 2 or 2½ drachms. It is situated imme-

diately below the base and the inner surface of the inferior maxilla, and above the digastric muscle. In this position it is covered by the skin and the platysma myoides, and its inner surface rests on the mylo-hyoid, hyo-glossus, and stylo-glossus muscles; above, it corresponds with a depression on the inner surface of the jaw-bone; and it is separated behind from the parotid gland merely by the stylo-maxillary membrane. The facial artery, before it mounts over the jaw-bone, lies in a deep groove upon the back part and upper border of the gland.

The *duct* of the submaxillary gland, named *Wharton's duct*, which is about two inches in length, passes off from the gland, together with a thin process of the glandular substance, round the posterior border of the mylo-hyoid muscle, and then runs forwards and inwards above that muscle, between it and the hyo-glossus and genio-hyo-glossus, and beneath the sublingual gland, to reach the side of the frænum linguæ. Here it terminates, close to the duct of the opposite side, by a narrow orifice, which opens at the summit of a soft papilla seen beneath the tongue. The structure of this gland is like that of the parotid; but its lobes are larger, its surrounding areolar web is finer, and its attachments are not so firm. Moreover, its duct has much thinner coats than the parotid duct.

The blood-vessels of the submaxillary gland are branches of the facial and lingual arteries and veins. The nerves include those derived from the small submaxillary ganglion, as well as branches from the mylo-hyoid division of the inferior dental nerve, and the sympathetic.

The Sublingual Gland.

The *sublingual gland*, the smallest of the salivary glands, is of a narrow oblong shape and weighs scarcely one drachm. It is situated along the

Fig. 573.

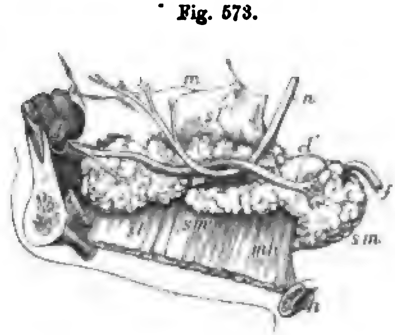


Fig. 573.—View of the Right Submaxillary and Sublingual Glands from the Inside.

A part of the right side of the jaw, divided from the left at the symphysis, remains; the tongue and its muscles have been removed; but the mucous membrane of the right side is retained and is drawn upwards so as to expose the sublingual glands. *s m*, the larger superficial part of the submaxillary gland; *f*, the facial artery passing through it; *s m'*, deep portion prolonged within the mylo-hyoid muscle *m h*; *s l*, is placed below the anterior large part of the sublingual glands, with the duct of Bartholin partly shown; *s l'*, placed above the hinder small end of the chain of glands, indicates the ducts of one or two perforating the mucous membrane; *d*, the papilla, at which the duct of Wharton opens in front behind the incisor teeth; *d'*, the commencement of the duct; *h*, the hyoid bone; *n*, the gustatory nerve.

floor of the mouth, where it forms a ridge between the tongue and the gums of the lower jaw, covered only by the mucous membrane. It reaches from the frænum linguæ, in front, where it is in contact with the gland of the opposite side, obliquely backwards and outwards for rather more than an inch and a half. On its inner side it rests on the genio-hyo-glossus; beneath, it is supported by the mylo-hyoid muscle, which is interposed

between it and the submaxillary gland; but it is here in close contact with the Whartonian duct, with the accompanying deep portion of the last-named gland, and also with the lingual nerve.

The lobules of the sublingual gland are not so closely united together as those of the other salivary glands, and the ducts from many of them open separately into the mouth, along the ridge which indicates the position of the gland. These ducts, named *ducts of Rivini*, are from eight to twenty in number. Some of them open into the duct of Wharton. One, longer than the rest (which is occasionally derived in part also from the submaxillary gland), runs along the Whartonian duct, and opens either with it or very near it; this has been named the duct of Bartholin.

A. Fig. 574. B.

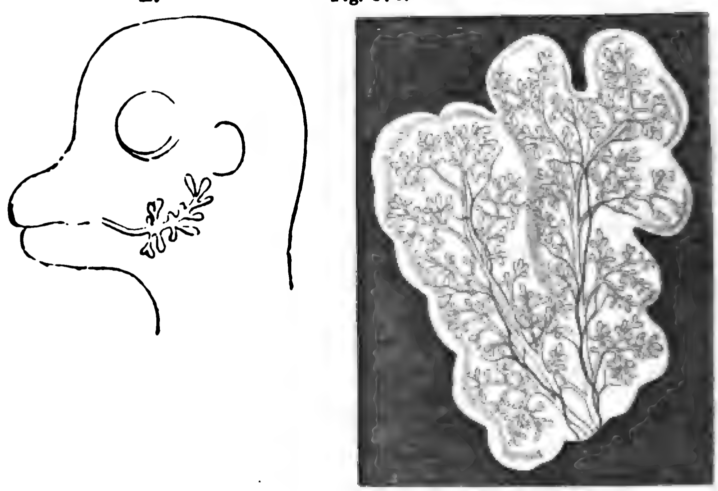


Fig. 574.—Sketches Illustrating the Formation of the Parotid Gland (from J. Müller).

A, head of a fœtal sheep magnified, showing the early simple condition of the parotid gland with the duct injected.
B, parotid gland of a fœtal sheep more advanced, the ducts and blood-vessels injected.

The blood-vessels of this gland are supplied by the sublingual and submental arteries and veins. The nerves are numerous, and are derived from the lingual branch of the fifth pair.

Saliva.—The saliva is a clear limpid fluid, containing a few microscopic granular corpuscles. Its specific gravity is from 1·006 to 1·008, and it has only from 1 to 1½ parts of solid matter in 100. The saliva is always alkaline during the act of mastication; but the fluid of the mouth becomes acid, and remains so until the next time of taking food: the reason being that the secretion of the mucous follicles of the mouth is acid, while that of the salivary glands is alkaline. Its chief ingredients, besides water and mucus, are a peculiar animal extractive substance, named salivine, with some alkaline and earthy salts. It is remarkable, besides, for containing a minute proportion of sulphocyanide of potassium.

Development.—In mammalia, according to Müller and Weber, the salivary glands as shown in the case of the parotid gland in the embryo of the sheep, first appear in the form of a simple canal with bud-like processes lying in a blastema, and communicating with the cavity of the mouth. This canal becomes more and more ramified to form the ducts, whilst the blastema soon acquires a lobulated form, corresponding with that of the future gland, and at last wholly disappears, leaving the branched ducts, with their blood-vessels and connecting tissues. The submaxillary gland is said to be the first formed; then the sublingual and the parotid.

THE PHARYNX.

The pharynx is that part of the alimentary canal which unites the cavities of the mouth and nose to the œsophagus. It extends from the base of the skull to the lower border of the cricoid cartilage, and forms a sac open at the lower end, and imperfect in front, where it presents apertures leading into the nose, mouth, and larynx.

The velum pendulum palati projects backwards into the pharynx, and during the passage of the food completely separates an upper from a lower part by means of the contraction of the muscles connected with it which are placed in the posterior pillars of the fauces. Seven openings lead into the cavity of the pharynx; viz., above the velum, the two posterior openings of the nares and, at the sides, the apertures of the Eustachian tubes; while below the velum, there is first the passage leading from the mouth, then the superior opening of the larynx, and lastly the passage into the œsophagus.

The walls of the pharynx consist of a fascia or layer of fibrous tissues, named the pharyngeal aponeurosis, dense at its upper part but lax and weak below, surrounded by muscles, and lined by a mucous membrane. At its upper end this fibrous wall is attached to the posterior margin of the body of the sphenoid bone, and passes outwards to the petrous portion of the temporal. It is strengthened in the middle line by a strong band descending between the recti antici muscles from a part of the basilar process which often presents a marked tubercle.

The pharynx is usually described as attached superiorly to the basilar process of the occipital bone; it is certain, however, from dissections in both young and old subjects, that the recti capitis antici muscles come quite forward to the anterior extremity of the basilar process; that the posterior wall of the pharynx at its upper end forms a cul-de-sac on each side opposite the tip of the petrous bone, and lies in a curve, with its convexity forwards, in front of the recti muscles; and that the only connection of the pharynx with the occipital bone is by means of the mesial band, which has been described, and which forms a cranio-pharyngeal ligament. The tubercle from which this band principally springs is sometimes named *tuberculum pharyngeum*.

Behind, the wall of the pharynx is loosely connected by areolar tissue to the prevertebral fascia covering the bodies of the cervical vertebræ and the muscles which rest upon them. At the sides, the walls have similar connections, by loose areolar tissue, with the styloid process and its muscles, and with the large vessels and nerves of the neck. In front, they are attached in succession to the sides of the posterior nares, the mouth, and the larynx. Thus, commencing above by a tendinous structure only, at the petrous portion of the temporal bone and the Eustachian tube, the walls are connected by means of muscle and fibrous membrane, first, with the internal pterygoid plate, then with the pterygo-maxillary ligament, and next with the mylo-hyoid ridge of the lower jaw; below this, they are attached

to the sides of the tongue, to the hyoid bone, and stylo-hyoid ligament; and, still lower down, to the thyroid and cricoid cartilages.

The pharynx is about four inches and a half in length, and is considerably wider across than it is deep from before backwards. Its width above is moderate; its widest part is opposite the cornua of the hyoid bone, and below this it rapidly contracts towards its termination, opposite the cricoid cartilage, where it is narrowest.

Structure.—The *muscles* of the pharynx are the superior, middle and inferior constrictors, the stylo-pharyngeus, and the palato-pharyngeus. They are described at page 187.

The *mucous* membrane lining the inner surface of the pharynx is continuous at the several apertures with that of the adjacent cavities. It varies somewhat in its character in different parts. Its upper portion is

Fig. 575.

Fig. 575.—Antero-Posterior Vertical Section through the Head a little to the left of the Middle Line, showing the relations of the Nasal and Buccal Cavities, the Pharynx, Larynx, &c.

a, nasal septum, and below it the section of the hard palate; *b*, the tongue; *c*, soft palate; *d*, the lips; *u*, the uvula; *r*, anterior pillar of the fauces; *i*, posterior pillar; *t*, the tonsil placed between the pillars; *p*, upper part of the pharynx; *h*, body of the hyoid bone; *k*, thyroid cartilage; *n*, cricoid cartilage; *v*, on the upper vocal cords above the glottis; *s*, epiglottis; 1, posterior opening of the nares; 3, behind the isthmus faucium; 4, opposite the superior opening of the larynx; 5, passage into the œsophagus; 6, opening of the right Eustachian tube.

thick where it adheres to the periosteum of the basilar process, but is much thinner near the entrance of the Eustachian tube and the posterior nares: in this situation numerous *glands* are found collected in a layer beneath the mucous membrane. The glands are of two kinds, viz., racemose, which are especially numerous in the upper portion; and simple or compound follicular, which exist throughout the whole of the pharynx. A chain of glands, forming a glandular mass, exactly similar to that of the tonsils, stretches across the

back of the fauces between the orifices of the two Eustachian tubes (Kölliker). In the part opposite the fauces, the mucous membrane exactly resembles that of the mouth. Lower down it becomes paler, and at the back of the larynx it forms several longitudinal folds or plicæ. According to Henle, the epithelium upon the upper portion of the pharynx, as low down as a horizontal line level with the floor of the nares, is columnar and ciliated; but, below that point, it is squamous and destitute of cilia.

THE ŒSOPHAGUS.

The *œsophagus* or gullet, the passage leading from the pharynx to the stomach, commences at the cricoid cartilage opposite the lower border of the fifth cervical vertebra, and, descending along the front of the spine, passes through the diaphragm opposite the ninth dorsal vertebra, and there ends by opening into the cardiac orifice of the stomach.

The length of the œsophagus is about nine or ten inches. It is of smaller diameter than any other division of the alimentary canal, its narrowest part being at the commencement behind the cricoid cartilage; it is also slightly constricted in passing through the diaphragm, but, below that, gradually widens into the stomach. The œsophagus is not quite straight in its direction, but presents three slight curvatures. One of these is an antero-posterior flexure, corresponding with that of the vertebral column in the neck and thorax. The other two are slight lateral curves; for the œsophagus, commencing in the median line, inclines to the left side as it descends to the root of the neck; thence to the fifth dorsal vertebra it gradually resumes the mesial position; and finally, it deviates again to the left, at the same time coming forward towards the œsophageal opening of the diaphragm. In the lower cervical and upper dorsal region the œsophagus is applied to the anterior surface of the spine, being connected with it and with the longus colli muscle by loose areolar tissue; but between it and the bodies of the upper dorsal vertebræ the thoracic duct ascends obliquely from right to left: its lower third is placed in front of the aorta. In the *neck*, the œsophagus lies close behind the trachea, and the recurrent laryngeal nerves ascend in the angles between them; on each side is the common carotid artery, and also a part of the thyroid body, but, as the œsophagus inclines to the left side, it is in more immediate connection with the left carotid.

In the *thorax*, the œsophagus is successively covered in front by the lower part of the trachea, by the commencement of the left bronchus, and by the back of the pericardium. The aorta, except near the diaphragm, where the œsophagus is in front of the vessel, lies rather to the left, and the vena azygos to the right; the pneumogastric nerves descend in close contact with its sides, and form a plexus around it, the left nerve proceeding gradually to the front, and the right nerve retiring behind it. Lastly, the œsophagus, which is here placed in the interval between the two pleuræ, comes partially in contact with both of those membranes.

Structure.—The walls of the œsophagus are composed of three coats; viz., an external or muscular, a middle or areolar, and an internal or mucous coat. Outside the muscular strata, there is a layer of fibrous tissue, with well marked elastic fibres, which is sometimes spoken of as a distinct coat.

The *muscular* coat consists of an *external* longitudinal layer, and an *internal* circular layer. This twofold arrangement of the muscular fibres

prevails throughout the whole length of the alimentary canal ; but the two layers are here much thicker, more uniformly disposed, and more evident than in any other part except quite at the lower end of the rectum. The external or *longitudinal* fibres are disposed at the commencement of the tube in three fasciculi, one in front, and one on each side of the œsophagus. The lateral fasciculi are blended above with the inferior constrictor of the pharynx ; the anterior fasciculus arises from the back of the cricoid cartilage at the prominent ridge between the posterior crico-arytenoid muscles, and its fibres spreading out obliquely on each side of the gullet as they descend, soon blend with those of the lateral bundles to form a continuous layer around the tube. The internal or *circular* fibres are separated

Fig. 576.

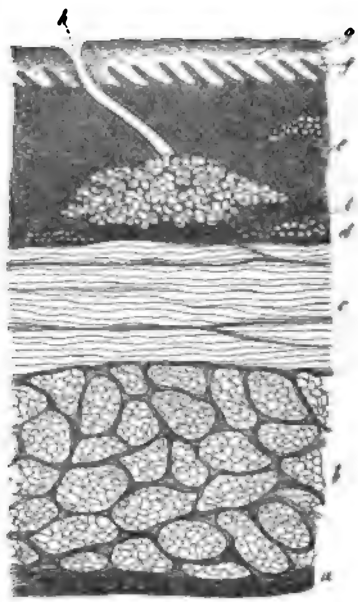


Fig. 576.—Section of the Coats of the Human Œsophagus (from Kölliker). $\frac{50}{1}$

The section is transverse, and from near the middle of the gullet. *a*, fibrous covering; *b*, divided fibres of the longitudinal muscular coat ; *c*, transverse muscular fibres; *d*, submucous or areolar layer ; *e*, mucous membrane ; *f*, its papillæ ; *g*, laminated epithelial lining ; *h*, opening of a mucous gland, of which the cellular part is seen embedded deeply in the mucous membrane; *i*, fat vesicles.

above by the fibres of the longitudinal fasciculi from those of the inferior constrictor of the pharynx. The rings which they form around the tube have a horizontal direction at the upper and lower part of the œsophagus, but in the intervening space are slightly oblique. At the lower end of the œsophagus, both layers of fibres become continuous with those of the stomach.

The muscular coat of the upper end of the œsophagus is of a well-marked red colour, and consists of striped muscular fibres ; but lower down it becomes somewhat paler, and is principally composed of the plain muscular fibres. A few striped fibres, however, are found mixed with the others, and have been traced throughout its whole length, and even, it is said, upon the cardiac end of the stomach. (Ficinus.)

The longitudinal fibres of the œsophagus are observed by Hyrtl to be sometimes joined by a broad band of smooth muscle, passing upwards from the left pleura, and sometimes also by another from the left bronchus.

The *areolar* coat is placed between the muscular and mucous coats, and connects them loosely together.

The *mucous membrane* is of firm texture, and is paler in colour than that of the pharynx or stomach. From its loose connections its outer surface is freely movable on the muscular tunic ; and when the latter is contracted, as happens when the œsophagus is not giving passage to food, the mucous lining is thrown into longitudinal folds, the inner surfaces of which are in mutual contact. These folds again disappear on distension of the canal.

Minute papillæ are seen upon this mucous membrane, placed at some distance from each other, and the whole is covered with a thick squamous epithelium, which can be traced as far as the cardiac orifice of the stomach, where it suddenly passes into one of a different character, as will be hereafter noticed.

The gullet is provided with many small compound racemose glands, named *œsophageal glands*, which are especially numerous at the lower end of the tube.

Dilatations occasionally occur in the course of the œsophagus. Diverticular pouches are also sometimes found, but appear in all cases to be of hernial origin. Duplicity of the œsophagus in part of its extent, without other abnormality, has been recorded (Blaes, quoted by Meckel).

THE ABDOMINAL PORTION OF THE DIGESTIVE ORGANS.

As that part of the digestive canal which is found beneath the diaphragm, and consists of the stomach and intestines, is situated within the cavity of the *abdomen*, and occupies, together with the liver (the secretion of which it receives), by far the greater part of that cavity, the topographic relations of the abdominal viscera may here be briefly explained.

THE ABDOMEN.

The abdomen is the largest cavity in the body, and is lined by an extensive and complicated serous membrane, named the peritoneum.

It extends from the diaphragm above, to the levatores ani muscles below, and is subdivided into two parts: an upper and larger part, *the abdomen*, properly so called; and a lower part, named the *pelvic cavity*. The limits between the abdominal and pelvic portions of the cavity are marked by the brim of the pelvis.

The enclosing walls of this cavity are formed principally of muscles and tendons which have been already described (p. 248). They are strengthened internally by a layer of fibrous tissue lying between the muscles and the peritoneum, the different parts of which are described under the names of fascia transversalis, fascia iliaca, and anterior lumbar fascia (p. 257). These walls are pierced by several apertures, through which are transmitted the great vessels and some other parts, such as the several diaphragmatic apertures for the aorta, vena cava, and œsophagus, and the femoral arches and inguinal canals. In the median fibrous substance of the anterior wall lies the umbilical cicatrix. The cavity of the pelvis is also lined with strong fasciæ (p. 260), and partially by peritoneum, and at its lower part it presents the apertures for the transmission of the rectum and the genito-urinary passages.

For the purpose of enabling precise reference to be made to the situation and condition of the contained organs, the *abdomen proper* has been artificially subdivided into certain regions, the boundaries of which are indicated by lines drawn upon the surface of the body. Thus, two horizontal lines drawn round the body divide the cavity into three zones: viz. an upper, a middle, and a lower. One of these lines, commencing at the most prominent point of the lower costal cartilages of one side, is drawn across to the corresponding point on the opposite side, and thence horizontally round the back to the place at which it began. The other line, proceeding from the crest of the ilium of one side, extends to that of the other, and so round the body, as in the former instance. Each of these zones again is subdivided

into three parts by means of two perpendicular lines, drawn from the cartilage of the eighth rib, on each side, down to the centre of Poupart's ligament.

The upper zone is thus marked off into the right and left *hypochondriac* regions and the *epigastric* region, the depression in the upper part of which is called *scrobiculus cordis*, or pit of the stomach. The middle zone is divided into the *umbilical* region in the centre, and the right and left *umbar* regions; and the inferior zone into the *hypogastric* region in the centre, and the *iliac* region at each side.

On opening the abdominal cavity from the front, the viscera are seen to lie in an upper and lower group, separated by the great omentum, which overhangs those in the lower part. The surfaces, which are in contact one with another, and with the wall of the cavity, are rendered glistening by reflections over them of the lining membrane of the cavity, the *peritoneum*; and the various organs are found to be attached by means of folds or duplicatures of that membrane, termed mesenteries and omenta, which include the blood-vessels, nerves, and lymphatics belonging to each organ. In the upper group, as seen from before, are comprised the liver, stomach, and a small part of the intestine; in the lower group, more or less hidden by

Fig. 577.

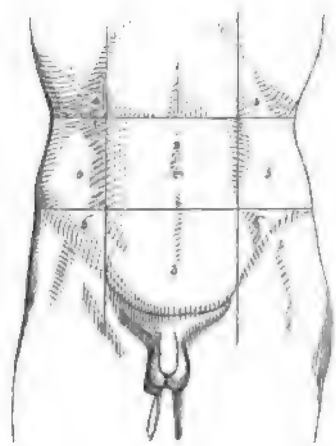


Fig. 577.— Outline of the Anterior Surface of the Abdomen, showing the Division into Regions.

1, epigastric region; 2, umbilical; 3, hypogastric; 4, 4, right and left hypochondriac; 5, 5, right and left lumbar; 6, 6, right and left iliac.

the great omentum, are the remaining parts of the alimentary canal. The spleen, pancreas, and kidneys constitute a deeper group.

On the right side, projecting downwards from beneath the diaphragm is the *liver* with its excretory apparatus, which occupies the right hypochondrium and part of the epigastrium, and extends a short way into the left hypochondrium; to the left, and partly beneath the liver, is the stomach, which lies in the epigastric and left hypochondriac regions; and closely applied to the left or cardiac end of the stomach is the *spleen*.

The *stomach* is seen to be connected at its right extremity, named the pylorus, with the *small intestine*. The first part of the small intestine, named *duodenum*, forms a deep curve projecting towards the right side, resting on the posterior wall of the abdominal cavity and right kidney, and terminating at the left of the middle line, where it emerges from behind the root of the mesentery, and passes into the second part of the intestine, named *jejunum*. The hollow of the curve of the duodenum is occupied by the large right extremity or head of the pancreas. The remainder of the small intestine, comprising the *jejunum* in its upper two-fifths, and the *ileum* in the

lower three-fifths, is disposed in moveable convolutions, and is attached posteriorly by a broad mesentery to the abdominal wall. It occupies the umbilical and hypogastric regions, from the back part of which the mesentery takes origin, and it extends likewise into the lumbar and iliac regions, besides gravitating into the pelvis. The ileum terminates abruptly in the right iliac region in the *caput cæcum*, a cul-de-sac in which the *great intestine* commences. The cæcum is continued into the *ascending colon*, which lies against the posterior wall of the abdomen, as it passes up through the right lumbar to the right hypochondriac region. The ascending colon is succeeded by the *transverse colon* which passes transversely, or with a pendulous curve, across the abdomen from right to left, resting on the small intestines. Below

Fig. 578.

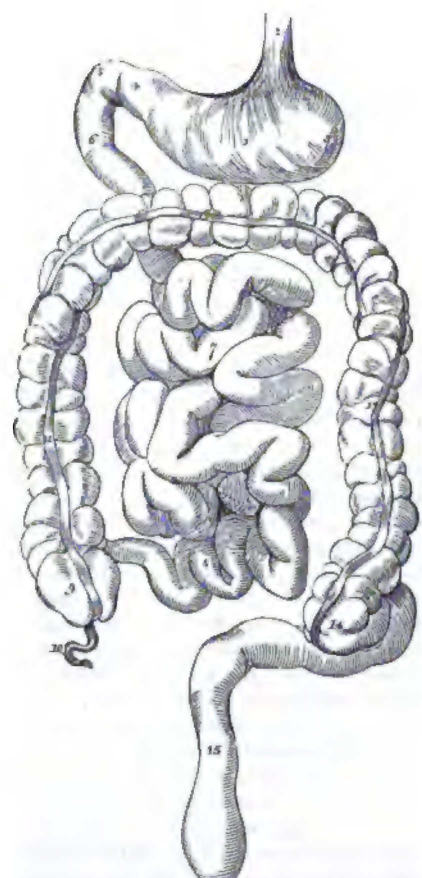


Fig. 578.—Diagram of the Abdominal Part of the Alimentary Canal.

1, the stomach; 2, the lower part of the gullet; 3, the left cul-de-sac, and, 4, the pyloric end of the stomach; 5, 6, the duodenum; 7, 8, convolutions of the small intestine; 9, cæcum; 10, the vermiform process; 11, ascending, 12, transverse, and, 13, descending colon; 14, commencement of the sigmoid flexure; 15, rectum.

the spleen, the transverse colon is continued into the *descending colon* which extends down through the left lumbar to the left iliac region, where it is continued into the more loosely-bound *sigmoid flexure*, which occupies that fossa and falls into the *rectum*.

Within the pelvis, the extension downwards of the peritoneal cavity is termed the *recto-vesical fossa*: posteriorly the rectum is observed, and anteriorly the sloping upper wall of the *urinary bladder*; while, in the female, the *uterus* projects upwards between the rectum and bladder, so that a recto-uterine pouch is formed, and the *ovaries* and *Fallopian tubes* are pendant at its sides. The bladder when full, and the uterus in its gravid state, project upwards into the abdomen, and displace more or less of the small intestine.

Subjoined is an enumeration of the organs situated in the different regions of the abdomen.

PARTS SITUATED IN EACH REGION OF THE ABDOMEN.

Epigastric region	The middle part of the stomach, with its pyloric extremity, the left lobe of the liver, the hepatic vessels and lobulus Spigelii, the pancreas, the cœliac axis, the semilunar ganglia, part of the vena cava, and also, as they lie between the crura of the diaphragm, part of the aorta, the vena azygos and thoracic duct.
Hypochondriac, right	The right lobe of the liver, with the gall-bladder, part of the duodenum, the hepatic flexure of the colon, the right supra-renal capsule, and part of the corresponding kidney.
Hypochondriac, left	The large end of the stomach, with the spleen and narrow extremity of the pancreas, the splenic flexure of the colon, the left supra-renal capsule and upper part of the left kidney. Sometimes also a part of the left lobe of the liver.
Umbilical	Part of the omentum and mesentery, the transverse part of the colon, transverse part of the duodenum, with some convolutions of the jejunum and ileum.
Lumbar, right	The ascending colon, lower half of the kidney and part of the jejunum.
Lumbar, left	The corresponding parts of the opposite side.
Hypogastric	The convolutions of the ileum, the bladder in children, and, if distended, in adults also; the uterus when in the gravid state.
Iliac, right	The cæcum, ileo-cæcal valve, the ureter, and spermatic vessels.
Iliac, left	The sigmoid flexure of the colon, the ureter and spermatic vessels.

THE PERITONEUM.

The peritoneum or serous membrane of the abdominal cavity is by far the most extensive and complicated of the serous membranes. Like the others it may be considered to form a shut sac, on the outside of which are placed the viscera which it covers. In the female, however, the two Fallopian tubes open at their free extremities into the cavity of the peritoneum. The internal surface is free, smooth, and moist, and is covered by a thin squamous epithelium. The external or attached surface adheres partly to the parietes of the abdomen and pelvis, and partly to the outer surface of the viscera situated within them. The *parietal* portion is connected loosely with the fascia lining the abdomen and pelvis by means of a layer of areolar tissue, distinct from the abdominal fasciæ, and named the *sub-peritoneal* or *retro-peritoneal* layer; but it is more firmly adherent along the middle line of the body in front, as well as to the under surface of the diaphragm. The *visceral* portion, which is thinner than the other, forms a more or less perfect investment to most of the abdominal and pelvic viscera.

The folds of the peritoneum are of various kinds. Some of them, constituting the *mesenteries*, connect certain portions of the intestinal canal with the posterior wall of the abdomen; they are, the mesentery properly so called for the jejunum and ileum, the meso-cæcum, transverse and sigmoid meso-colon, and the meso-rectum. Other duplicatures, which are called *omenta*, proceed from one viscus to another; they are distinguished as the great omentum, the small omentum, and the gastro-splenic omentum. Lastly, certain reflexions of the peritoneum from the walls of the abdomen or pelvis to viscera which are not portions of the intestinal canal, are named *ligaments:* these include the ligaments of the liver, spleen, uterus, and bladder.

If the examination of the peritoneal folds be commenced on the under surface of the diaphragm, it will be found that on the left side it can be traced back to the posterior wall of the abdomen, and down in front of the upper part of the kidney to the commencement of the descending colon. Further to the right, it is reflected from the diaphragm over the front of the stomach, and from the left of the stomach passes across a very short interval to the spleen, which it completely invests; and it is continued back from the spleen to the abdominal wall. Still further to the right, the peritoneum is reflected from the diaphragm to the liver, invests the whole superior surface of that organ, and passes round its anterior and lateral margins to invest the whole of its inferior surface, with the exception only of so much as lies behind the portal fissure, viz., the lobule of Spigelius. On the upper surface of the liver the peritoneum is thrown into a right and a left fossa by a vertical antero-posterior fold attaching it to the diaphragm, which is named the *falciform* or *suspensory ligament* of the liver. In the lower margin of this ligament a fibrous cord, consisting of the obliterated remains of the umbilical vein, and named the *round ligament* of the liver, extends upwards from the umbilicus to the longitudinal fissure which divides inferiorly the right lobe of the liver from the left; and it is the reflection of the peritoneum from this cord which forms the falciform ligament. The thick posterior border of the liver, uninvested with peritoneum, is in contact with the diaphragm; and the reflexions of peritoneum from the upper and under surfaces of the organ to the parietes above and below this border constitute the *coronary ligament*. Towards the right and left extremities of the liver the superior and inferior layers of the coronary ligament come into contact for a little way, and form the *right* and *left triangular ligaments* of the liver.

The portion of peritoneum reflected from the under surface of the liver, opposite the portal fissure, passes down over the vena portæ, hepatic artery, and biliary ducts, to the pyloric extremity of the stomach and first part of the duodenum; while that which invests the part of the liver to the right of the portal fissure is conducted back to the posterior wall of the abdomen. If now, the disposition of the peritoneum be examined in the spot where those two modes of arrangement meet, an aperture sufficiently large to admit a finger, and formed by invagination of the peritoneum, will be found leading, from right to left, behind the hepatic vessels and duct: this aperture is the *foramen of Winslow;* and the fold of peritoneum in front of it, containing the portal vein, hepatic artery, and biliary ducts, is termed the *small* or *gastro-hepatic omentum*. The foramen of Winslow has above it a portion of the liver; behind it the vena cava inferior; below it the duodenum; and in front the small omentum. The invagination of peritoneum which takes place at the foramen of Winslow is of great extent, expanding to form a large pouch, which lies behind the stomach, and stretches downwards to a variable degree in front of the transverse colon. This is the *sac of the omentum* or *smaller cavity of the peritoneum*, which will be presently described.

On tracing downwards the peritoneum investing the anterior surface of the stomach, it is seen to be prolonged from the inferior border of that viscus to form a pendulous fold of omentum lying loosely in front of the colon and small intestines, and having a free margin inferiorly. Folding backwards on itself at this margin, the peritoneum passes upwards to the transverse colon and becomes adherent to its surface, whence it is continued back to the abdominal wall.

The sac of the omentum may be laid open by means of an incision a little

Fig. 579.

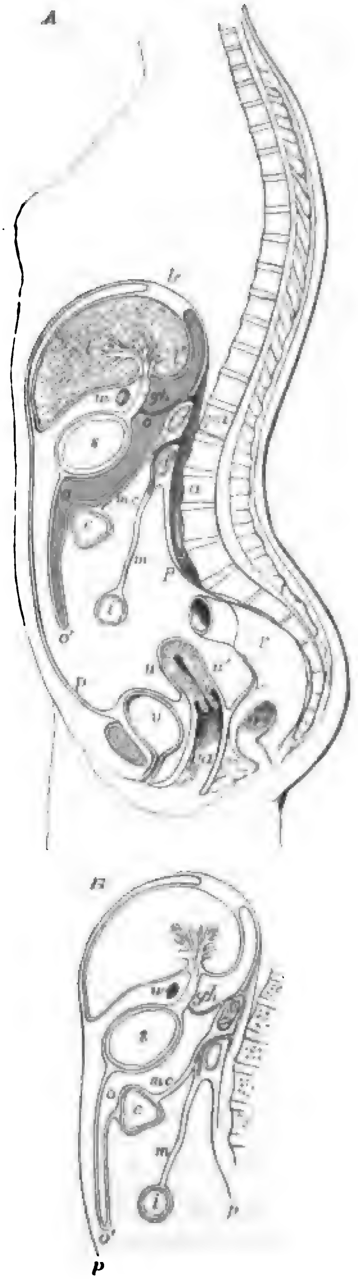


Fig. 579, A.—Diagrammatic Outline of a supposed Section of the Body, showing the Inflections of the Peritoneum in the Female. ⅛

The upper part of the section is a little to the right of the mesial plane of the body, through the quadrate and Spigelian lobes of the liver; below it is supposed to be mesial: *l c*, placed above the diaphragm opposite to the coronary ligament of the liver; *l*, the liver; *l'*, lobe of Spigel; *s*, stomach; *c*, transverse colon; *i*, the small intestine; *p a*, pancreas; *d*, the duodenum; *v*, urinary bladder; *u*, uterus; *r*, rectum; *r'*, its middle part opened; *v a*, vagina; *p*, *p*, the parietal peritoneum lining the front and back of the abdominal cavity; the line representing the inflections of the greater sac of the peritoneum will be traced from the neighbourhood of *l c*, where it passes on the upper surface of the liver over the upper and lower surfaces of that organ, in the front of *g h*, the gastro-hepatic omentum, over the front of the stomach, down to *o'*, the outer layer of the great omentum, whence, according to the most received view, it passes back to the vicinity of the pancreas, and re-descends as the upper layer of the transverse meso-colon; after enclosing the colon it returns on the lower surface of the transverse meso-colon, *m c*, to the root of the mesentery, *m*; it now forms the mesentery and encloses the small intestine, returning to the duodenum and posterior wall of the abdomen, whence it passes over the rectum, *r*, descends into the recto-vaginal pouch, *u'*, covers the back and front of the uterus and the bladder partially and regains the anterior abdominal wall above the pubes; as connected with the lesser sac of the peritoneum, *w*, marks the position of the foramen of Winslow as if seen in perspective beyond the section; the lesser sac with the sac of the omentum is shaded with horizontal lines, and is marked *o o*: round this space the line of the peritoneum may be traced from the diaphragm over the lobe of Spigel, to the back of the gastro-hepatic omentum, thence behind the stomach and down into the sac of the omentum; it then ascends to the pancreas, which it covers, and thence reaches again the diaphragm.

B, is a sketch of part of a section similar to that of A, but showing the different view frequently taken, according to which the two layers of the meso-colon after enclosing the colon descend to form the posterior pair of the layers of the great omentum.

below the great curvature of the stomach. It will then be seen that the inner wall of this sac, having invested

the posterior surface of the stomach and commencement of the duodenum, is continued downwards, back to back with the general peritoneum, into the pendulous portion of the omentum, and, as it returns thence, is applied to the anterior surface of the transverse colon. Passing these parts, it resumes its position of proximity to the peritoneum of the greater sac, and proceeds to the posterior wall of the abdomen. The two layers of peritoneum which thus hang pendulously one within the other, and are derived from the general and the smaller sac, contitute the *gastro-colic* or *great omentum*; while those by which the transverse colon is connected with the abdominal wall are termed the *transverse mesocolon*. In the pendulous great omentum, there being a duplication of both the general peritoneum and the wall of the smaller sac, four layers are to be distinguished, viz., first, an anterior and a posterior layer belonging to the greater sac of the peritoneum, having their smooth surfaces respectively directed forwards to the abdominal wall and backwards to the small intestines; and second, between these, the anterior and posterior layers derived from the lesser sac, lining the omental cavity and gliding one against the other: these four layers are, however, so intimately united and reduced to such extreme tenuity in the adult, that they cannot be separately recognised in the omentum below the colon. In most instances the pendulous part of the omentum presents the appearance of lacework, the interstices of which in corpulent persons are more or less loaded with fat. In some subjects, instead of lying like an apron over the small intestine, it is crumpled into a bundle along the transverse colon, as if displaced by the movements of the intestines against the wall of the abdomen.

The description now given of the great omentum and transverse mesocolon agrees with the appearances most frequently seen in the adult subject, and with the account usually given in English works of Anatomy, the posterior layer of the great omentum being described as separating from the layer within, belonging to the omental sac, when it reaches the transverse colon, so as to pass behind or below that viscus, and from thence as proceeding backwards to the abdominal wall as the posterior or lower layer of the transverse meso-colon. It was, however, long ago pointed out by Haller, and the view has been confirmed by the observations of J. F. Meckel, J. Müller, Hansen, and Huschke, that in the fœtus, and occasionally in the child, or even in the adult, the two posterior layers of the omentum, though adherent to the transverse colon, may be separated from it and from the transverse meso-colon, so as to demonstrate that the transverse meso-colon is really a distinct duplicature of peritoneum. This view has been adopted by Holden and Luschka in their more recent works, and has been verified by Allen Thomson. Figures 579 A, and B, show diagrammatically the difference of the two views.

The anterior wall of the sac of the omentum invests the whole posterior surface of the stomach; above the small curvature of the stomach it lies back to back with the general peritoneum, completing in conjunction with it a *gastro-phrenic* ligament; and further to the right it forms the posterior layer of the gastro-hepatic omentum, and likewise invests the lobulus Spigelii of the liver, close to the foramen of Winslow. Lying transversely in front of the aorta and in contact with the posterior wall of the abdomen, the pancreas is seen invested anteriorly by the hinder wall of the sac of the omentum. To the left of the stomach the sac extends to the spleen, and usually gives investment to a small portion of that organ at the lower end of its hilus it thus forms the posterior layer of the *gastro-splenic omentum*,

the fold by which the spleen is attached to the stomach. The splenic artery lies behind the sac of the omentum in its course to the spleen, but its gastric branches turn round the splenic margin of the sac and reach the stomach by that means. The coronary artery of the stomach reaches the front of the sac by turning round its upper margin; and the hepatic artery passes round from below, close to the foramen of Winslow.

The disposition of the peritoneum below the level of the transverse meso-colon is comparatively simple. The mesentery of the small intestine, although greatly frilled out in front to correspond in length with the jejunum and ileum to which it affords support, is attached posteriorly by a very short border which extends from the level of attachment of the transverse colon immediately to the left of the middle line, directly down to the right iliac fossa, where the ileum falls into the cæcum. At its widest part the length of the mesentery is from four to six inches between its vertebral and its intestinal border. Between the two layers of serous membrane of which it consists are placed, besides some fat, numerous branches of the superior mesenteric artery and vein, together with nerves, lacteal vessels, and mesenteric glands. In the right and left lumbar region the peritoneum invests the ascending and descending colon usually in less than their whole circumference, and thus binds them closely down to the abdominal parietes, without the intervention of a meso-colon. In some cases the cæcum is suspended at a short distance from the right iliac fossa, by a distinct duplicature of the peritoneum, which is termed the *meso-cæcum*; but, more commonly, the peritoneum merely binds down this part of the large intestine, and forms a distinct but small mesentery for the vermiform appendix only. The sigmoid flexure is attached to the left iliac fossa by a considerable mesentery, the *sigmoid meso-colon*; and in the pelvis the rectum is attached by a fold named *meso-rectum*. The other peritoneal folds within the pelvis will be mentioned elsewhere.

Along the colon, and upper part of the rectum, the peritoneum is developed into numerous little projections filled with adipose tissue. These fatty processes are named *appendices epiploicæ*.

At the upper end of the attachment of the mesentery, on its left side, there is always visible a small portion of the terminal part of the duodenum appearing from underneath in about half its breadth; and on the right side of the mesentery there is often another little angle of duodenum visible between the mesentery and meso-colon. Thus it will be observed that while the commencement of the duodenum is invested, like the stomach, in front by the general peritoneum and behind by the sac of the omentum, and a succeeding portion is invested only in front, the remainder is crossed by the colon and mesentery, and is only to a small extent in contact with peritoneum.

THE STOMACH.

The stomach is that dilated portion of the alimentary canal which intervenes between the œsophagus and the duodenum, and within which the food is retained for a time to be acted on by the gastric juice, and to be converted into chyme.

This organ is seated in the left hypochondriac and the epigastric regions, extending also into the right hypochondrium. It lies in part against the anterior wall of the abdomen, and in part beneath the liver and diaphragm, and above the transverse colon.

The stomach is of a somewhat conical or pyriform shape. The left extremity is the larger, and is named the cardiac, *great* or *splenic* end. The *right* or *small* end is also named the *pyloric* extremity. Of its two orifices, the one by which food enters from the œsophagus is named the *cardiac* orifice, the other, by which it passes into the duodenum, and which is placed on a somewhat lower level, and more forwards, is the *pyloric* orifice.

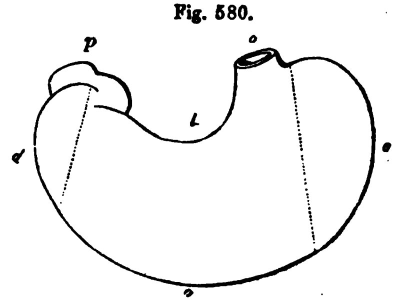
The œsophagus terminates in the stomach two or three inches from the great extremity, which projects beyond the place of union to the left, forming the *great cul-de-sac* or *fundus*.

Between the cardiac and the pyloric orifices, the outline of the stomach is curved along its upper and lower borders. The upper border, about three or four inches in length, is concave, and is named the *lesser* curvature; while the lower border, which is much longer, and, except towards the pylorus, convex, forms the *greater* curvature.

Fig. 580.—Diagrammatic Outline of the Stomach. ⅙

a, great curvature; *b*, lesser curvature; *c*, left end, great cul-de-sac, or fundus; *d*, small cul-de-sac or antrum pylori; *o*, œsophageal orifice or cardia; *p*, duodenal orifice or pylorus.

Fig. 580.



Towards the pylorus, the small end of the stomach describes a double bend, opposite to the first turn of which is a prominence or bulging, sometimes named the *small cul-de-sac* or *antrum pylori*.

Division of the stomach, by constriction, into a right and left pouch, is frequently observed as a temporary condition resulting from spasm. More rarely it is of a permanent character (Struthers, Monthly Med. Journ., 1851).

Dimensions.—These vary greatly, according to the state of distension of the organ. When moderately filled, its length is about ten or twelve inches; and its diameter at the widest part, from four inches to four inches and a half. According to Clendinning, it weighs, when freed from other parts, about four ounces and a half in the male, and somewhat less in the female.

Connections.—The borders of the stomach are connected with folds of peritoneum in their whole extent. Thus, to the superior border is attached the gastro-phrenic ligament and gastro-hepatic omentum; to the inferior border is attached the gastro-colic omentum; and to the left extremity the gastro-splenic omentum. The blood-vessels and lymphatics of the stomach pass within these duplicatures of the peritoneum, and reach the organ along its two curvatures. Its anterior and posterior surfaces are free, smooth, and covered with peritoneum. The anterior surface, which is directed upwards as well as forwards, is in contact above with the diaphragm and the under surface of the liver, and lower down with the abdominal parietes opposite to the epigastric region, which is hence named the *pit* of the *stomach*. The posterior surface is turned downwards and backwards, and rests upon the transverse meso-colon, and farther back, upon the pancreas and great vessels of the abdomen.

At its cardiac orifice it is continuous with the œsophagus, and is, therefore, fixed to the œsophageal opening in the diaphragm. The pyloric extremity, situated lower down, nearer to the surface, and having greater freedom of motion, is continuous with the duodenum. It is covered by the concave surface of the liver, and in some cases touches the neck of the gall-bladder.

When the stomach is distended, its position and direction are changed. The œsophageal end, being fixed to the back part of the diaphragm, cannot undergo any considerable change; but the duodenal extremity has more liberty of motion. The lesser curvature is, also, somewhat fixed to the liver by the small omentum, while the great curvature is the most movable part: accordingly, when the stomach is distended, this curvature is elevated and at the same time carried forwards, whilst the anterior surface is turned upwards, and the posterior surface downwards.

Structure.—The walls of the stomach consist of four distinct coats, held together by fine areolar tissue. They are named, in order from within outwards, the serous, muscular, areolar or submucous, and mucous coats. By some the areolar coat is not reckoned as a separate tunic. Taking all the coats together, the walls of the stomach are thinner than those of the œsophagus, but rather thicker than those of the intestines generally. They are thickest at the pyloric end, and thinnest in the great cul-de-sac.

The *external* or *serous* coat, derived from the peritoneum, is a thin, smooth, transparent, and elastic membrane which closely covers the entire viscus, excepting along its two curvatures. Along the line of these curvatures the attachment is looser, leaving an interval occupied by the larger blood-vessels.

The second or *muscular* coat is composed of three sets of unstriped fibres, disposed in three layers, and named, from their direction, the longitudinal, the circular, and the oblique fibres.

The first or outermost layer consists of the *longitudinal* fibres, which are in direct continuity with those of the œsophagus. They spread out in a radiating manner from the cardiac orifice, and are found in greatest abundance along the curvatures, especially on the lesser one. On the anterior and posterior surfaces they are very thinly scattered, or are scarcely to be found. Towards the pylorus they are arranged more closely together and form a thicker uniform layer, which, passing over the pylorus, becomes continuous with the longitudinal fibres of the duodenum.

The second set consists of the *circular* fibres, which form a complete layer over the whole extent of the stomach. They commence by small and thinly scattered rings at the left extremity of the great cul-de-sac, describe larger and larger circles as they surround the body of the stomach concentric to its curved axis, and towards the pyloric end again form smaller rings, and at the same time become much thicker and stronger than at any other point. At the pylorus itself, they are gathered into an annular bundle, which projects inwards into the cavity, and forms, together with areolar tissue and the lining mucous membrane, the pyloric sphincter and valve. Some of the circular fibres appear to be continued from those of the œsophagus, spreading from its right side. According to Pettigrew the fibres of this layer are not, as usually described, mere rings or circles, but rather double loops in the form of the figure of eight, the two parts of which cross each other very obliquely.

The innermost muscular layer is incomplete, and consists of the *oblique*

fibres. These oblique fibres are continuous with the layer of circular fibres of the gullet; they embrace the cardiac orifice on the left, where they form a considerable stratum, and from that point descend obliquely upon the

Fig. 580*.

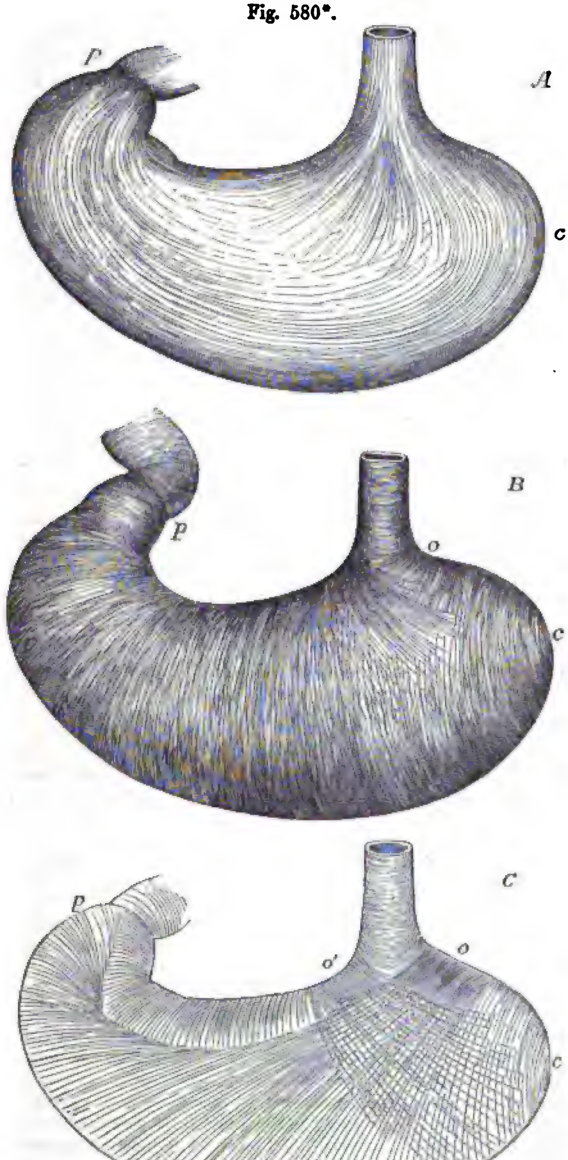


Fig. 580*.—SKETCH OF THE DISTRIBUTION OF MUSCULAR FIBRES IN THE STOMACH (after Pettigrew and from nature). ½

A, external layer of longitudinal fibres, as seen from the outside; B, middle layer of circular fibres as seen on removing the longitudinal layer; C, deepest layer of oblique fibres as seen from within, after inverting the stomach and removing the mucous membrane: *c*, the cardiac end; *p*, the pyloric end; in A, the stronger longitudinal fibres passing along the lesser and greater curvatures, and all round the pyloric end are shown, and the radiating fibres spreading from the root of the gullet over the front and back of the stomach; in B, the nearly uniform layer of circular fibres in two sets crossing each other very obliquely and becoming concentric at the cardiac end to the centre of the great cul-de-sac; in C, the very oblique bands of fibres which form a continuation of the circular fibres of the gullet and spread in two sets, *o*, *o'*, one from the right and the other from the left side of the cardia (also partially represented in B), passing over the front and back of the stomach (except its lesser curvature) as far as the pyloric end.

anterior and posterior surfaces of the stomach, where they spread out from one another, and most of them gradually disappear; some, however, reach as far as the pylorus. A similar set of fibres, noticed by Henle, and more fully described by Pettigrew, proceed from the right side of the cardia and spread over the front and back of the great cul-de-sac: these are in part continuous with the circular layer. The oblique fibres are best seen from the inside of the stomach, after removing the mucous membrane. In this, as in the circular layer of fibres, Pettigrew believes the figure of 8 arrangement to prevail. (From unpublished Notes of Researches on the Muscular Fibres of the Stomach, by James Pettigrew, M.D.)

Fig. 581.

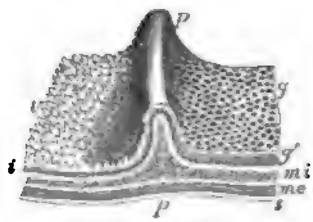


Fig. 581.—Diagrammatic View in Perspective of a Portion of the Coats of the Stomach and Duodenum, including the Pylorus. ½

g, the alveolar surface of the stomachal mucous membrane; *g'*, section of the mucous membrane with the pyloric gastric glands; *v*, the villous surface of the mucous membrane of the duodenum; *i*, section of the same with the intestinal glands or crypts of Lieberkühn; *pp*, the ridge of the pyloric valve, with a section of its component parts; *mi*, deep or circular layer of muscular fibres: these are seen in the section to form a part of the pyloric valve; *me*, external or longitudinal layer of muscular fibres; *s*, the serous covering.

The *areolar* or submucous coat of the stomach is a distinct layer placed between the muscular and mucous coats, and connected with both: it consists essentially of a dense filamentous areolar tissue, in which occasional fat-cells may be found; and it is the seat of division and passage of the larger branches of the blood-vessels.

The internal or *mucous* coat is a smooth, soft, rather thick and pulpy membrane, which has generally a somewhat pink hue owing to the blood in its capillary vessels, but which, after it has been well washed, is of a greyish white or pale straw colour. In some cases, however, it presents this pale aspect without any previous washing. In infancy the vascular redness is more marked, the surface having then a rosy hue, but it becomes paler in childhood, and in aged persons is often of an ash-grey colour. During digestion its vessels become congested, and when examined in that condition it is always of a much brighter pink than at other times.

After death a few hours often suffice to change its colour to a dirty brown tint, mottled and streaked in some cases with dull red lines, corresponding with the course of the veins. This alteration is owing to the exudation of the colouring matter of the blood, and is especially met with in old subjects, in whom the mucous membrane is always thin. In acute inflammation, or after the introduction of irritating substances or of strong acrid poisons, it becomes of a bright red, either all over or in spots, patches or streaks of variable sizes. Corrosive poisons, the gastric juice, and sometimes regurgitating bile, may stain it variously, black, brown, yellow, or green: and the effect of chronic inflammation is to leave the membrane of a slate-grey colour. Independently of all these modifying circumstances connected with the stomach itself, as was pointed out by Yelloly and others, the colour of the gastric mucous surface is liable to be influenced by causes of a more general nature. Thus, it has been found that in cases of obstructed venous circulation, as when death occurs from hanging or from drowning, and also in certain diseases of the heart, the internal surface of the stomach is reddened to a greater or less extent; but the amount of vascularity may vary from circumstances which are not well understood, and may be found greatly increased in cases in which none of those now named exist. Trans. of Med. Chir. Soc., vol. iv. p. 371.

The gastric mucous membrane is thickest in the pyloric portion of the stomach, and thinnest in the great cul-de-sac. It always becomes thinner in old age.

The outer or *adherent* surface of the mucous membrane is connected with the muscular coat by means of the intervening submucous layer so loosely as to allow of considerable movement or displacement. In consequence of this, and of the great extent and want of elasticity of the mucous membrane as compared with the other coats, the internal surface of the stomach, when that organ is in a contracted state, is thrown into numerous convoluted ridges, *rugæ*, which are produced by the wrinkling of the mucous, together with the areolar coat, and are entirely obliterated by distension of the stomach. These folds of the mucous coat are most evident along the great curvature, and have a general longitudinal direction.

On examining the gastric mucous membrane closely with the aid of a simple lens, it is seen to be marked throughout, but more plainly towards the pyloric extremity, with small depressions or cells named *alveoli*, which have a polygonal figure, and vary from about $\frac{1}{200}$th to $\frac{1}{100}$th of an inch across, being larger and more oblong near the pylorus.

Fig. 582.

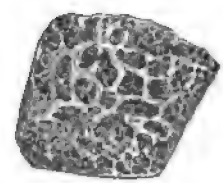


Fig. 582.—Enlarged View of a small part of the Surface of the Mucous Membrane of the Stomach (from Ecker). $\frac{20}{1}$

This specimen shows the shallow alveoli, in each of which the smaller dark spots indicate the orifices of a variable number of the gastric glands.

Towards the pyloric region of the stomach, where the mucous membrane is thicker than elsewhere, the margins of these alveoli are elevated into pointed processes or fringes, which may be compared to rudimentary *villi*, the perfect forms of those appendages existing only in the small intestine, and making their appearance in the duodenum, immediately beyond the pylorus.

Fig. 583.

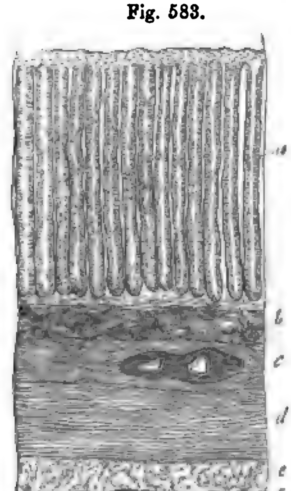


Fig. 583.—Vertical Transverse Section of the Coats of a Pig's Stomach (from Kölliker). $\frac{30}{1}$

a, gastric glands; *b*, muscular layer of the mucous membrane; *c*, submucous or areolar coat; *d*, circular muscular layer; *e*, longitudinal muscular layer; *f*, serous coat.

At the bottom of the alveoli, and also in the intervals between them, are seen small round apertures, which are the mouths of minute tubes, placed perpendicularly to the surface, closed at their attached or deep extremity, which rests on the submucous areolar tissue, and opening at the other on the inner surface of the stomach. On making a vertical section of the membrane, and submitting it to microscopic examination, it is seen to consist almost entirely of these small *tubuli*, arranged close to and parallel with each other. Their diameter varies from $\frac{1}{300}$th to $\frac{1}{360}$th of

an inch, and their length from $\frac{1}{80}$th to $\frac{1}{20}$th of an inch. At the cardiac end of the stomach, where the membrane is thinnest, they are shorter and are simply tubular; but, in approaching the pyloric portion, they gradually become longer

Fig. 584.

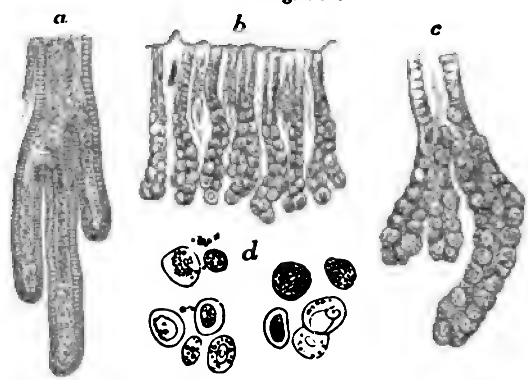


Fig. 584.—The Gastric Glands of the Human Stomach (magnified).

a, the deep part of a pyloric gastric gland (from Kölliker); the cylindrical epithelium is traceable to the cæcal extremities.

b, *c*, and *d*, cardiac gastric glands (from Allen Thomson). *b*, vertical section of a small portion of the mucous membrane with the glands magnified 30 diameters; *c*, deeper part of one of the glands, magnified 65 diameters, showing a slight division of the tubes, and a sacculated appearance produced by the large glandular cells within them; the change of the prismatic epithelium into spherical gland cells within the tube is apparent; *d*, cellular elements of the cardiac glands, magnified 250 diameters.

and assume a more complicated form, for though quite straight near their orifices, they are curved, clavate, or irregularly sacculated towards their

Fig. 585.

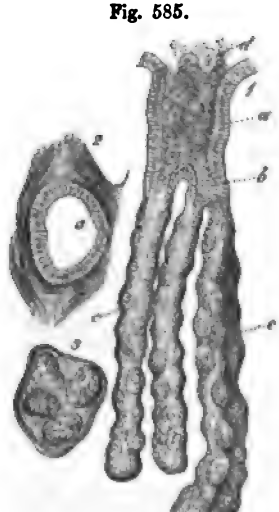


Fig. 585.—Peptic Gastric Glands from the Dog's Stomach, magnified (from Frey).

1, longitudinal view; *a*, the main duct; *b*, one of the first tubular divisions of the gland; *c*, the single tubes occupied by the gastric or peptic cells; *d*, some of the cells pressed out; 2, cross section of the main duct, showing the epithelial lining; 3, cross section of the simple tubes.

deep or closed extremity. Some are cleft, first into two or three, and finally into six or eight tubular branches. These characters are most perfect near the pylorus. They exist at all parts of the stomach, even where the alveoli are indistinct or absent; they contain a colourless fluid, with granular matter, and appear to be the secreting organs of the gastric mucus and the gastric juice. The tubuli, generally, are formed of a simple homogeneous membrane; fusiform cells supposed to be muscular lie between them on their contiguous or attached sur-

faces ; and their inner surface is lined with cells. At the pyloric end of the stomach these cells appear to be entirely lined with a simple layer of columnar epithelium ; but in other portions of the organ, only the upper fourth of the tubuli is occupied by epithelium of that character ; the lower three-fourths containing finely granular nucleated cells, which are polygonal or oval in form, are much larger than the columnar, and do not form a stratum on the surface, but completely fill the cavity : these have been termed peptic cells. It has been supposed that only those glands which possess the last mentioned form of epithelium secrete the gastric juice, and they have accordingly been named *peptic glands*, and distinguished from the *mucous glands*, in which the epithelium is columnar throughout.

A marked distinction has been made out by various observers between peptic and mucous glands of the stomach in the lower animals. Not only have their anatomical characters been found to be different, but likewise their physiological properties, as it has been ascertained that the gastric secretion only possesses its peculiar solvent properties when proceeding from those parts of the stomach which contain glands of the peptic kind. An abrupt separation, however, between the two varieties of gland does not appear to exist in the human subject. (Henle, Syst. Anat. d. Mensch., vol. ii., p. 158, where also other works are referred to.)

Lenticular follicles, similar to those of Peyer's glands, are found in the mucous membrane of the stomach, sometimes studding the greater part of its surface, and giving occasionally a granular or mammillated appearance to it. They are found in greater or less numbers all over the stomach, but are most numerous towards the pylorus. They are best seen in the stomachs of infants and children. Around the cardiac orifice they assume the character of multilocular crypts. They are more frequently found open than shut, the membrane which covers them being extremely delicate. (Allen Thomson, in Goodsir's Annals, i., p. 36.)

A distinct but delicate epithelium exists all over the stomach, covering the margins and floors of the alveoli, and lining the tubuli also. It belongs for the most part to the columnar variety, alternating in some parts with the squamous, which is composed of very minute polygonal scales.

In animals, there is a more or less distinct layer of muscular fibres in intimate relation with the simple basement membrane. These fibres are of the plain or unstriped variety, and are quite distinct from those which constitute the true muscular coat, being separated from them by the submucous areolar layer.

Vessels and nerves.—The stomach is a highly vascular organ. Its *arterial* branches, derived from all three divisions of the cœliac axis, reach the stomach between the folds of the peritoneum, and form, by anastomosing together, two principal arterial arches, which are placed along its two curvatures. After ramifying between the several coats and supplying them with blood, and especially after dividing into very small vessels in the submucous areolar tunic, the ultimate arterial branches enter the mucous membrane, and ramifying freely, pass to its surface between the tubuli; here they form a plexus of very fine capillaries upon the walls of the tubules; and from this plexus larger vessels pass into a coarser capillary network upon the hexagonal borders of the alveoli. The *veins*, corresponding with the arteries, arise from the latter network (Brinton, "Stomach and Intestine" in Cyclop. of Anat.), and after forming a wide venous plexus in the submucous tissue, return the residual blood into the splenic and superior mesenteric veins, and also directly into the vena portæ. By the breaking up of the arteries into capillaries on the walls of the glands, these are furnished with pure blood for the elaboration of their secretion ; while it is the blood from which that secretion has been drawn which passes on to the capillaries of the free surface, and has added to it whatever materials may be taken into the circulation from the contents of the stomach.

The *absorbents* are very numerous; arising from a very fine superficial plexus immediately underlying the tubular glands, they form a coarser deeply situated network, between the areolar and muscular coats; the vessels proceeding from this network pierce the muscular coats, then follow the direction of the blood-vessels beneath the peritoneal investment, and traverse lymphatic glands found along the two curvatures of the stomach. No trace of lymphatics has been found between the tubuli, therefore the whole depth of the secreting structure intervenes between the layer of lymphatics and the contents of the stomach, whereas capillary blood-vessels are distributed close to the surface; an arrangement which seems favourable for the interchange of material between the contents of the stomach and those of the blood-vessels rather than of the lymphatics.

The *nerves*, which are large, consist of the terminal branches of the two pneumo-gastric nerves, belonging to the cerebro-spinal system, and of offsets from the sympathetic system, derived from the solar plexus. Numerous small ganglia have been found by Remak and others on both the pneumo-gastric and sympathetic twigs. The nerves may be traced through the submucous coat, but no farther, as they then lose their tubular character, and cannot be distinguished from other tissues. (Kölliker.) The left pneumo-gastric nerve descends on the front, and the right upon the back of the stomach.

The Pylorus.—While there is no special apparatus at the cardiac orifice of the stomach for closing the passage from the œsophagus, the opening at the pyloric end, leading from the stomach into the duodenum, is provided with a sphincter muscle. On looking into the pyloric end of the stomach, the mucous membrane is seen projecting in the form of a circular fold, called the *pylorus*, leaving a correspondingly narrow opening. Within this fold are circular muscular fibres, belonging to the general system of circular fibres of the alimentary canal, which are here accumulated in the form of a strong band, whilst the longitudinal muscular fibres and the peritoneal coat pass over the pyloric fold to the duodenum, and do not enter into its formation. Externally the pylorus may be easily felt, like a thickened ring, at the right end of the stomach. Internally its opening is usually circular, and less than half an inch across, so that it is the narrowest part of the whole alimentary canal. (See figures 581 and 586.)

Occasionally the orifice is oval, and it is often placed a little to one side. Sometimes the circular rim is imperfect, and there are found instead two crescentic folds, placed one above and the other below the passage (Huschke); and, lastly, there is occasionally but one such crescentic fold.

THE SMALL INTESTINE.

The *small intestine* reaches from the pylorus to the ileo-cæcal valve, at which it opens into the large intestine. It consists of a convoluted tube, measuring on an average about twenty feet in length in the healthy adult, and becoming gradually slightly narrower from its upper to its lower end. Its numerous convolutions occupy the middle regions of the abdomen, and are surrounded by the large intestine. They are connected with the back of the abdominal cavity, and are held in their position by a covering and fold of the peritoneum, named the mesentery, and by numerous blood-vessels and nerves.

The small intestine is arbitrarily divided into three portions, which have received different names; the first ten or twelve inches immediately succeeding to the stomach, and comprehending the widest and most fixed part of the tube, being called the *duodenum*, the upper two-fifths of the remainder being named the *jejunum*, and the lower three-fifths the *ileum*. There

are no distinct lines of demarcation between these three parts, but, there are certain peculiarities of connection and certain differences of internal structure to be observed in comparing the upper and lower ends of the entire tube, which will be pointed out after it has been described as a whole.

DUODENUM.—This is the shortest and widest part of the small intestine. In length it measures 10 or 12 inches, or nearly the breadth of *twelve* fingers; hence its name.

It is the widest part of the small intestine, varying in diameter between an inch and a half and two inches. In its course it describes a single large curve somewhat resembling a horse-shoe, the convexity of which is turned towards the right, whilst the concavity embraces the head of the pancreas.

It has no mesentery, and is covered only partially by the peritoneum. Its muscular coat is comparatively thick, and its mucous membrane towards the pylorus is the seat of the compound glands of Brunner, to be subsequently described. The common bile duct and the pancreatic duct open into this part of the intestinal canal.

Fig. 586.

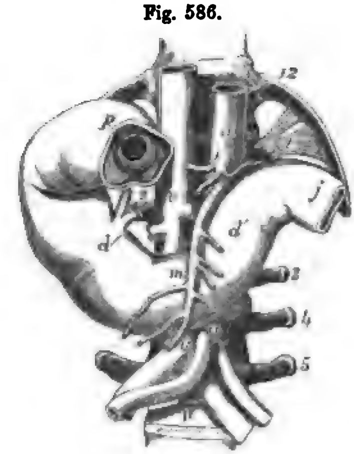


Fig. 586.—VIEW OF THE DUODENUM FROM BEFORE (slightly altered from Luschka). ½

12, the twelfth dorsal vertebra and rib; 1, 3, 4, 5, transverse processes of the first, third, fourth, and fifth left lumbar vertebræ; 2, that of the second on the right side; *a*, *a*, the abdominal aorta above the cœliac axis and near the bifurcation; *m*, superior mesenteric artery; *v*, *v*, the vena cava above the renal veins and near the bifurcation; *p*, placed on the first part of the duodenum, points to the pyloric valve seen from the side next the stomach, of which a small part is left connected with the intestine; *d*, on the descending or second part of the duodenum, indicates the termination of the common bile duct and the pancreatic duct; *d'*, the third or oblique part of the duodenum; *j*, the commencement of the jejunum.

Three portions of the duodenum, differing from each other in their course and connections, are separately described by anatomists; viz. the superior, descending, and transverse portions.

The first, or *superior* portion, which is between two and three inches long, commences at the pylorus, and passing upwards, backwards, and to the right side, reaches as far as beneath the neck of the gall-bladder, where the intestine bends suddenly downwards. This first portion of the duodenum is for the most part free, and invested both in front and behind by the peritoneum. Above, and in front of it, are the liver and gall-bladder, and it is commonly found stained by the exudation of bile from the latter a few hours after death. Behind it is the hepatic duct, with the blood-vessels passing up to the liver.

The second, or *descending* portion, commencing at the bend below the neck of the gall-bladder passes vertically downwards in front of the right kidney, as low as the second or third lumbar vertebra, where the bowel turns across to the left to form the third portion. This part of the

duodenum is invested by the peritoneum on its anterior surface only,—the posterior surface being connected to the right kidney and the vertebral column by areolar tissue. In front is the transverse colon and meso-colon, the upper layer of which is continuous with the peritoneal covering of the duodenum. To the left is the head of the pancreas, which adapts itself to the shape of the intestine on that side. The common bile duct descends behind the left border of this part of the duodenum, and together with the pancreatic duct, which accompanies it for a short distance, perforates the coats of the intestine obliquely near the lower part of its left or concave border. In the interior of this part of the intestine the valvulæ coniventes appear numerously; and an eminence or papilla found about four inches below the pylorus, on the inner and back part of the intestine, marks the situation of the common orifice of the biliary and pancreatic ducts.

The third or *transverse* or oblique portion, somewhat the longest and narrowest, beginning on the right of the third lumbar vertebra, crosses in front of the second obliquely from right to left, and continuing to ascend obliquely for an inch or more, ends in the jejunum at the left side of the vertebral column. It is placed immediately behind the root of the transverse meso-colon, and the commencement of the mesentery, as has been already described, and has the vena cava inferior and the aorta behind it. At its termination it forms an abrupt angle with the commencement of the jejunum. This is due to its being maintained, at that point, in its position, by a strong fibrous band descending from the left crus of the diaphragm and the tissue round the cœliac axis. According to Treitz, muscular fibres come from both these sources to this part of the duodenum. In subjects in which the intestines are large and dilated, the curve of the duodenum may descend to the level of the iliac crest, but owing to the support given by the band alluded to, its terminal extremity maintains a uniform position. Close to this point the superior mesenteric vessels pass from beneath the pancreas to enter the mesentery on the surface of the duodenum.

Jejunum and Ileum.—The *jejunum*, originally so called from its having been supposed to be empty after death, follows the duodenum, and includes the upper two-fifths of the remainder of the small intestine, while the succeeding three-fifths constitute the *ileum*, so named from its numerous coils or convolutions. Both the jejunum and the ileum are attached and supported by the mesentery. The convolutions of the jejunum are situated in part of the umbilical and left iliac regions of the abdomen; while the ileum occupies part of the umbilical and right iliac regions, together with the hypogastric, and descends into the pelvis, from which its lower end, supported by the mesentery, which is here very short, ascends obliquely to the right and somewhat backwards, over the corresponding psoas muscle, and ends in the right iliac fossa, by opening into the inner side of the commencement of the large intestine. There is no defined limit between the jejunum and the ileum, but the character of the intestine gradually changes from its upper to its lower end, so that portions of the two intestines, remote from each other, present certain well-marked differences of structure, which may be here enumerated. Thus, the jejunum is wider, and its coats are thicker; it is more vascular, and therefore it has a deeper colour; its valvulæ conniventes are long, wide, and numerous; its villi are well developed; and the patches of Peyer's glands are smaller, less frequent, and sometimes confined to its lower part. The ileum, on the other hand, is narrower; its coats are thin-

ner and paler; the valvulæ conniventes are small, and gradually disappear towards its lower end; the villi are shorter; and the groups of Peyer's glands are larger and more numerous. The diameter of the jejunum is about one inch and a half, that of the ileum about one inch and a quarter. A given length of the jejunum weighs more than the same of the ileum.

At a point in the lower part of the ileum it is not very uncommon to find a cul-de-sac or *diverticulum* given off from the main tube. The origin of these diverticula is explained by reference to the history of development, from which it appears that they arise in connection with the ductus vitello-intestinalis, uniting the intestine with the umbilical vesicle. They are not to be confounded with hernial protrusions of the mucous membrane, which may occur at any point. (See Meckel's Handbook of Anatomy, French edition, vol. ii. p. 431.)

Structure of the Small Intestine.

Structure.—The walls of the small intestine, like those of the stomach, are composed of four coats, viz., the serous, muscular, areolar, and mucous.

The external or *serous* coat, derived from the peritoneum, almost entirely surrounds the intestinal tube in the whole extent of the jejunum and ileum, leaving only a narrow interval along one border of the intestine, where it is reflected from it and becomes continuous with the two layers of the peritoneal duplicature named the mesentery. The line at which this reflexion takes place is named the *attached* or *mesenteric border* of the intestine. The opposite border and sides of the tube, which are covered by the peritoneum, are quite free and movable upon the adjacent parts. The upper part, however, of the small intestine, named the duodenum, is but partially covered by the peritoneum, as has been already more particularly described.

The *muscular* coat consists of two layers of fibres; an outer longitudinal, and an inner or circular set. The *longitudinal* fibres constitute an entire but comparatively thin layer, and are most obvious along the free border of the intestine. The *circular* layer is much thicker and more distinct; its fibres are placed closely together, and run in a circular direction around the bowel, but it does not appear that they individually form perfect rings.

This muscular tunic becomes gradually thinner towards the lower part of the small intestine. It is pale in colour, and is composed of plain muscular fibres. The progressive contraction of these fibres, commencing in any part of the intestine, and advancing in a downward direction, produces the peculiar *vermicular* or *peristaltic* movement by which the digestive mass is forced onwards through the canal. In this movement the circular fibres are mainly concerned; but the longitudinal fibres also aid in it; and those found along the free border of the intestine may have the effect of straightening or unfolding, as it were, its successive convolutions.

The *areolar* or *submucous* coat of the small intestine is a tolerably distinct and whitish layer, of a loose texture, which is connected more firmly with the mucous than with the muscular coat, between which two it is placed. By turning a portion of the intestine inside out, and then blowing forcibly into the cavity, the areolar tunic may be inflated, the air being driven into its areolar tissue, through the part at which the peritoneal investment is wanting. It supports the mucous membrane, and forms a layer of loose substance in which the vessels divide and subdivide into smaller branches, preparatory to entering the mucous tissue. It consists of filamentous areolar tissue, mixed with fine elastic fibres.

The internal or *mucous* coat is characterised by presenting all over its inner surface a finely flocculent or shaggy appearance, like the pile upon velvet, owing to its being covered with multitudes of minute processes, named *villi*; hence it is also named the *villous* coat. It is one of the most vascular membranes in the whole body, and it is naturally of a reddish colour in the upper part of the small intestine, but becomes paler, and at the same time thinner towards the lower end. The mucous tissue contains beneath its basement membrane, a thin muscular layer, demonstrated easily in animals, but scarcely recognisable in man. It presents for consideration, 1, the large *folds* called *valvulæ conniventes*; 2, the *villi* and *epithelium*; 3, the *glands*.

1. *Valvulæ Conniventes.*—The folds and wrinkles found upon the inner surface of the œsophagus and stomach may be completely obliterated by full distension of those parts of the alimentary canal. In the lining membrane of the small intestine, however, there exist, beside such effaceable folds, other permanent ones, which cannot be obliterated, even when the tube is forcibly distended. These permanent folds are the *valvulæ conniventes*, or valves of Kerkring. They are crescentic projections of the mucous membrane, placed transversely to the course of the bowel, each of them reaching about one-half or two-thirds of the distance round the interior of the tube, and they follow closely one upon another along the intestine.

The largest of these valves are about two and a-half inches long and one-third of an inch wide at the middle or broadest part; but the greater number are under these dimensions. Large and small valves are often found to alternate with each other. Some of them are bifurcated at one end, and others terminate abruptly, appearing as if suddenly cut off. Each valve consists of a fold of the mucous membrane, that is, of two layers placed back to back, united together by the submucous or areolar tissue. They contain no part of the circular and longitudinal muscular coats. Being extensions of the mucous membrane, they serve to increase the absorbent surface to which the food is exposed, and at the same time they contribute to delay its passage along the intestine.

There are no valvulæ conniventes quite at the commencement of the duodenum; about an inch or somewhat more from the pylorus they begin to appear; beyond the point at which the bile and pancreatic juice are poured into the duodenum they are very large, regularly crescentic in form, and placed so near to each other that the intervals between them are not greater than the breadth of one of the valves: they continue thus through the rest of the duodenum and along the upper half of the jejunum; below that point they begin to get smaller and farther apart; and finally, towards the middle of the ileum, having gradually become more and more irregular and indistinct, sometimes even acquiring a very oblique direction, they altogether disappear.

2. *Villi.*—The *villi*, peculiar to the small intestine, and giving to its internal surface the velvety or villous appearance already spoken of, are small, elongated, and highly vascular processes, which are found situated closely together on every part of the mucous membrane, over the valvulæ conniventes, as well as between them. They are best displayed by placing a piece of intestine, well cleansed from its mucus, under water, and examining it with a simple lens. The prevalent form of the villi is that of minute, flattened, bell-shaped membranous processes; others are conical or cylindrical, or even clubbed, or filiform at the free extremity. A few are compound as if two or three villi were connected together at their base.

Their *length* varies from $\frac{1}{4}$th to $\frac{1}{3}$rd of a line, or even more; and the broad flattened kinds are about $\frac{1}{6}$th or $\frac{1}{8}$th of a line wide, and $\frac{1}{20}$th or $\frac{1}{24}$th of a line thick. They are largest and most numerous in the duodenum and jejunum, and become gradually shorter, smaller, and fewer in number in the ileum. In the upper part of the small intestine Krause has estimated their number at from 50 to 90 in a square line; and in the lower part at from 40 to 70 in the same space: he calculates their total number to be at least four millions.

The *structure* of the villi is complicated: each consists of a prolongation of the proper mucous layer, covered by epithelium and enclosing blood-vessels, one or more lacteal vessels, and fine muscular fibres, with a greater or less number of small granular corpuscles and fat globules, of various sizes.

Fig. 587.

Fig. 587.—Magnified View of the Blood-vessels of the Intestinal Villi.

The drawing was taken from a preparation injected by Lieberkühn, and shows in each villus a small artery and vein with the intermediate capillary network.

Fig. 588.

A. B.

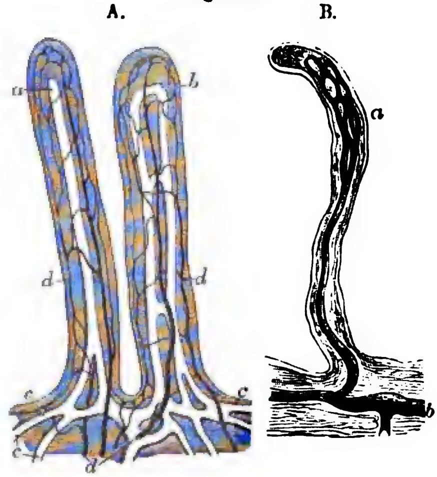


Fig. 588.—Injected Lacteal Vessels in the Villi of the Human Intestine.

A, two villi in which the lacteals are represented as filled with white substance and the blood-vessels with dark (from Teichmann) $\frac{100}{1}$: *a*, *b*, the lacteal vessels, single in one villus and double with cross loops in the other; *c*, the horizontal lacteal vessels with which those of the villi communicate; *d*, the blood-vessels, consisting of small arteries and veins with capillary network between.

B, injected lacteal in a villus (shaded dark), showing an example not very common of a looped network *a*, which is connected by a single vessel with the horizontal lacteal vessel *b*: the preparation was made from the intestine of a young man who died suddenly while digestion was going on (from W. Krause). $\frac{80}{1}$

Nerves have not yet been demonstrated in the villi, though they are probably not wanting. Each villus receives one or more small *arterial* twigs, which

divide, and form upon its surface, beneath the epithelium and limiting membrane, a fine capillary network, from which the blood is returned for the most part by a single *vein*.

The lacteal lies in the centre of the villus, and is in the smaller villi usually a single vessel, with a somewhat expanded extremity, and of considerably larger diameter than the capillaries of the blood-vessels around. According to the observations of Teichmann, there are never more than two intercommunicating lacteals in a single villus in the human subject; but both he and Frey find a copious network of them in the villi of the sheep. Considerable difference of opinion exists as to the nature of the wall of the lacteal in the villus, and even as to whether or not any wall exists, and this point must be considered as still undetermined. The epithelium of the villi is of the columnar kind; the cell wall is delicate, and the nucleus distinct. The nature of both the free and the attached extremities of the cells is involved

Fig. 589.

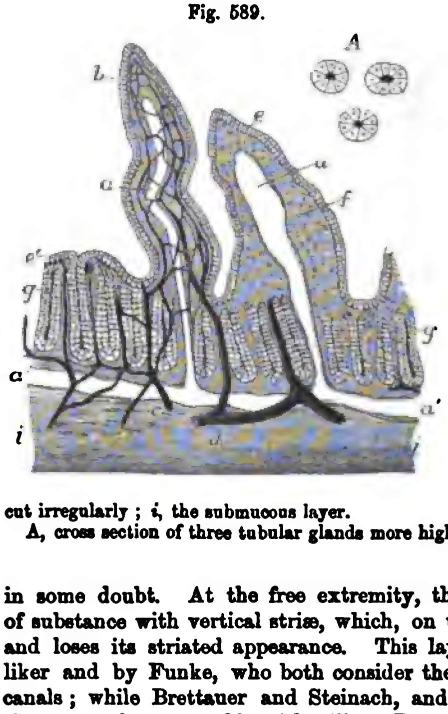


Fig. 589.—Vertical Section of the Intestinal Mucous Membrane of the Rabbit (slightly altered from Frey). $\frac{180}{1}$

Two villi are represented, in one of which the dilated lacteal alone is represented, in the other the blood-vessels and lacteal are both shown injected, the lacteal white, the blood-vessels dark: the section is carried through the tubular glands into the submucous tissue: *a*, the lacteal vessels of the villi; *a'*, below the glands, the horizontal lacteal, which they join; *b*, the capillary blood-vessels shown only in one of the villi; *c*, a small artery; *d*, a vein; *e*, the epithelium covering the villi; *f*, the substance of the villi, presenting interstices which contain lymph-cells; *g*, tubular glands or crypts of Lieberkühn, some divided in the middle, others cut irregularly; *i*, the submucous layer.

A, cross section of three tubular glands more highly magnified.

in some doubt. At the free extremity, they present to view a thick layer of substance with vertical striæ, which, on treatment with water, swells out and loses its striated appearance. This layer was first recognised by Kölliker and by Funke, who both consider the striæ to be minute perforating canals; while Brettauer and Steinach, and likewise Henle, maintain that they are rods comparable with cilia. Brücke, previous to the discovery of the striated body, advanced the opinion that the epithelium cells were altogether open at their free extremities, and that each communicated likewise with the interior of the villus by a foramen at the deep extremity. Brettauer and Steinach support Brücke's view, in respect that they consider the striated body as continuous with the cell contents, and not with the cell wall. With regard to the deep extremities of the epithelial cells, Heidenhain believes that he has observed them prolonged into fine threads, which communicate with branches of anastomosing connective-tissue-corpuscles, and considers

that by means of deep branches of these anastomosing cells opening into the cavity of the lacteal, a channel of communication is established between the lacteal and the surface of the villus. This view has met with some acceptance from its seeming to offer an explanation of the mode in which particles of oil are conveyed from the intestines into the lacteals; but it cannot

Fig. 590.

Fig. 590.—Epithelium of the Intestinal Villus of a Rabbit (from Kölliker). A, $\frac{300}{1}$; B, $\frac{350}{1}$

A, series of the cylindrical epithelial cells separated from a villus; a limiting or cuticular membrane or border is seen passing over the free ends of the cells.

B, some of the same cells treated with water; in 1 and 2, and at *a*, in the left hand series of cells, the striated or porous border is seen; and at *b*, in the latter, pellucid drops of mucus which have escaped from the cells.

at present be considered as satisfactorily established. The muscular tissue within the villi was first discovered by Brücke: it consists of a thin stratum of smooth fibres disposed longitudinally round the commencement of the lacteals. Although not always discernible in man, these fibres are distinct in animals; and in them, on being stimulated, they produce, according to Brücke, a very obvious retraction of the villi.

During digestion, the epithelial cells become turbid with minute oil drops in their interior, which obscure their nuclei. The tissue of the villus itself becomes turbid in like manner; and clear globules may also be observed, both in the epithelial cells and deeper tissue, which, however, there seems reason to believe, are formed by the running together of smaller particles after death. Kölliker and Donders have both observed minute particles of oil in their passage through the striated body.

A full bibliography, on the subject of the villi, is given by Teichmann in his work "das Saugadersystem," (1861), pp. 77 et seq.; and the questions at issue are fully discussed in Kölliker's Gewebelehre, 4th edition, and Henle's System. Anatomie. See also Frey, in Zeitsch. f. Wissensch. Zoologie, vol. xiii. Heidenhain's paper is in Moleschott's Untersuchungen z. Naturlehre, vol. iv. Peculiar epithelial cells with deeply hollowed cup-shaped extremities, have been pointed out by Henle, interspersed among the others. It is yet uncertain whether they are a distinct kind of cell, or only a peculiar condition of the ordinary sort.

3. *Glands.*—The glandular structures found in the mucous coat of the small intestine are the crypts or follicles of Lieberkühn, the solitary glands, the patches of Peyer's glands, and Brunner's glands, the last being peculiar to the duodenum.

The *crypts* of Lieberkühn, the smallest of these glandular structures, are found in every part of the small intestine, between the villi, and surrounding the larger glands. They consist of minute tubes, closed at their attached extremity, and placed more or less perpendicularly to the surface, upon

which they open by small orifices. They appear to be analogous to the tubuli of the stomach, but they are placed farther apart from each other, and are sometimes bulged inferiorly, but are hardly ever divided. Similar tubules also occupy the whole mucous membrane of the large intestine. The crypts of Lieberkühn vary in length from the $\frac{1}{30}$th to the $\frac{1}{10}$th of a line, and their diameter is about $\frac{1}{30}$th of a line. The walls of the tubes are thin, and lined with a columnar epithelium: their contents are fluid and transparent, with granules interspersed, and they never contain fat. These crypts are sometimes filled with a whitish substance, which most probably consists chiefly of desquamated epithelium and mucus.

The *agminated glands*, or *glands of Peyer* (who discovered and described them in 1677), are found in groups or patches, having an oblong figure, and

Fig. 591 A.

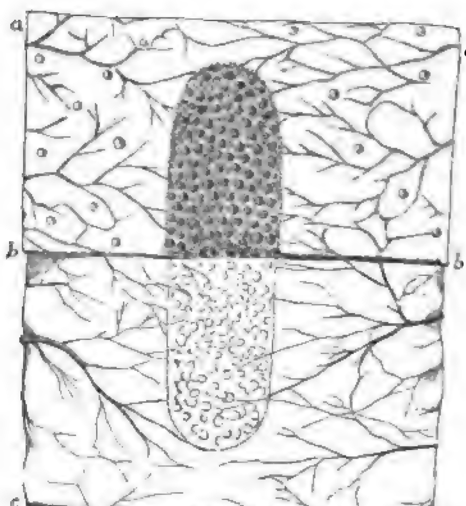


Fig. 591 A.—Patch of Peyer's Glands in the Ileum.

This figure represents, somewhat diagrammatically, and of the natural size, a patch of Peyer's glands from near the middle of the ileum of a young subject: in the lower half of the figure the mucous membrane and the glands have been removed by dissection, showing the impression left by the patch of glands by the condensation of the submucous tissue: the piece of intestine having been opened along its mesenteric border, the blood-vessels are seen advancing from the separated margins towards the centre.

varying from half an inch to two or even four inches in length, and being about half an inch, or rather more, in width. These patches are placed lengthways in the intestine at that part of the tube most distant from the mesentery; and hence, to obtain the best view of them, the bowel should be opened by an incision along its attached border.

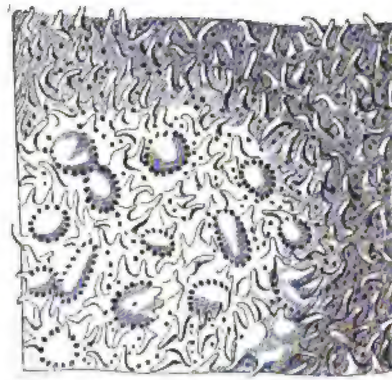
The patches of Peyer's glands consist of groups of small, round, flattened vesicles or capsules composed of a tolerably thick and firm wall of connective tissue, usually filled with a whitish or rather greyish semi-fluid matter, consisting of round nucleated cells and free nuclei, and situated beneath the mucous membrane, the surface of which is depressed into little shallow pits, at or rather under the bottom of which the capsules are placed. The intermediate surface of the membrane is beset with villi and Lieberkühn's crypts: the villi are also sometimes found even over the capsules, and the crypts are collected in circles around the capsules, but do not communicate with them. Opposite to the patches of Peyer's glands, the mucous and areolar coats of the intestine adhere more closely together than elsewhere, so that in those situations it is impossible to inflate the areolar coat. Fine blood-vessels are distributed abundantly on the walls of the capsules, and give off still finer capillary branches, which, supported by a delicate network of connective

tissue, spread through the cavity of each capsule among its semifluid contents, and are disposed principally in lines converging to the centre. In some subjects these small capsules are found almost empty, and then they are

Fig. 591 B.—ENLARGED VIEW OF A PART OF A PATCH OF PEYER'S GLANDS (from Boehm). $\frac{10}{1}$

The shaded part of the figure shows the surface of the intestinal mucous membrane in the vicinity of the patch occupied by villi, and between them the orifices of the crypts of Lieberkühn ; the lighter part of the figure, in which about a dozen of Peyer's vesicles may be seen, is also beset with villi, and in this part the crypts of Lieberkühn are arranged chiefly in circles round the vesicles.

Fig. 591 B.



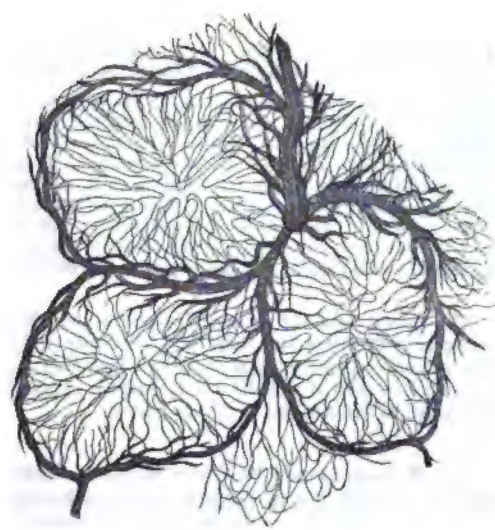
difficult of detection. They are usually entirely closed ; but the elder Krause observed that in the pig they were occasionally open, and a similar observation was made by Allen Thomson, not only in the pig, but in the human intestine also.

The lacteal plexuses, which are abundant in the whole extent of the in-intestine, are especially rich and composed of wide vessels, where they

Fig. 592.—TRANSVERSE SECTION OF INJECTED PEYER'S GLANDS (from Kölliker). $\frac{30}{1}$

The drawing was taken from a preparation made by Frey : it represents the fine capillary network spreading from the surrounding blood-vessels into the interior of three Peyer's capsules from the intestine of the rabbit.

Fig. 592.



surround the closed follicles, so closely indeed that these may be said to be imbedded in them ; but the lacteals do not penetrate the capsules as the capillary blood-vessels do.

It was formerly presumed without question that Peyer's and the other closed follicles in the alimentary tract constituted a peculiar capsular form of secreting glands ; but since the discovery of capillaries in their interior, and of the rich supply of absorbents around them, it has been supposed that they might be more immediately connected with the lymphatic system. This, however, is by no means proved ; for, although the interior of the capsules can no longer be compared with the cavities of

open glands, there is not sufficient evidence to show whether their contents pass into the intestinal tube or into the lacteals, from which they are as completely separated by intervening texture. The facts which have been ascertained as to their minute structure, and the nature of their contents, seem to bring them rather under the description of vascular glands. It may farther be stated as a point of analogy between them and those structures, that the glands of Peyer belong chiefly to youth. After middle life they become more or less flaccid and empty, and have generally completely disappeared in advanced age.

Fig. 593.

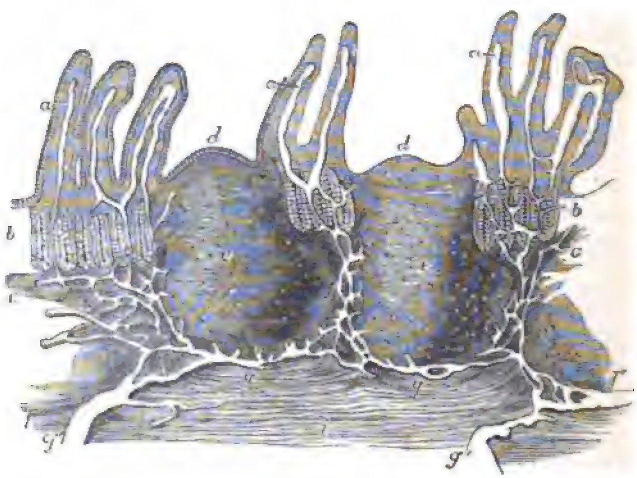


Fig. 593.—Vertical Section of a portion of a Patch of Peyer's Glands, with the Lacteal Vessels injected (from Frey). $\frac{32}{1}$

The specimen from which the drawing was made was obtained from the body of a man of twenty years of age who died suddenly from an injury, and is from the lower part of the ileum; the epithelium, not represented in the original, is introduced diagrammatically in one part : *a*, villi, with their lacteals left white; *b*, some of the tubular glands; *c*, the muscular layer of the mucous membrane; *d*, the cupola or projecting part of Peyer's vesicles; *e*, their central cavities or substance; *f*, the reticulated lacteal vessels occupying the "lymphoid" tissue between the vesicles, joined above by the lacteals from the villi and mucous surface, and passing below into *g*, the reticulated lacteals under the vesicles of Peyer, which pass into *g'*, the larger lacteals of the submucous layer *i*.

The observations of Frey and His have further shown that in the intervals between the glands of Peyer and those of Lieberkühn, and also in the substance of the villi, the interstices of the retiform tissue (see Histology, p. lxxix.) are everywhere occupied by granular cells of the size and appearance of lymph-cells, and very similar to those contained in the capsules of Peyer's glands.

In all, from twenty to thirty of these oblong patches may in general be found; but in young persons dying in health, as many as forty-five have been observed. They are larger and placed at shorter distances from each other, in the lower part of the ileum; but in the upper portion of that intestine and in the lower end of the jejunum, the patches occur less and less frequently, become smaller, and are of a nearly circular form; they may, however, be discovered occasionally in the lower portion of the duodenum.

Still smaller irregularly-shaped clusters of these capsules are found scattered throughout the intestine, and may be regarded as transitions to the next form of glands named *solitary*.

Fig. 594

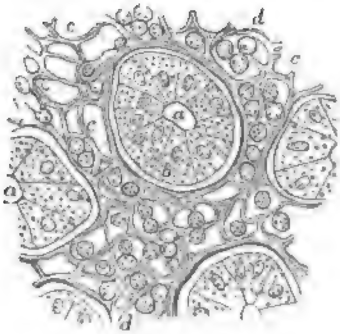


Fig. 594.—Lymphoid or Retiform Tissue of the Intestinal Mucous Membrane of the Sheep (from Frey). $\frac{400}{1}$

The figure represents a cross section of a small fragment of the mucous membrane, including one entire crypt of Lieberkühn and parts of several others: *a*, cavity of the tubular glands or crypts; *b*, one of the lining epithelial cells; *c*, the lymphoid or retiform spaces, of which some are empty, and others occupied by lymph cells, as at *d*.

The *solitary glands* (glandulæ solitariæ) are soft, white, rounded, and slightly prominent bodies, about the size of a millet-seed, which are found scattered over the mucous membrane in every part of the small intestine. They are found on the mesenteric as well as on the free border, between and upon the valvulæ conniventes, and are rather more numerous in the lower portion of the bowel. These small glands have no orifice, but consist of closed vesicles or capsules, exactly resembling those forming the clusters of Peyer's glands, having rather thick but easily destructible walls, and usually containing in their interior an opaque, semifluid substance, which abounds in cells and fine granules. The free surface of the capsules, which is slightly elevated when they are full, is beset with the intestinal villi; and, placed around them very irregularly, are seen the open mouths of the crypts of Lieberkühn.

Fig. 595.

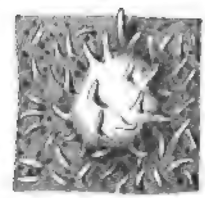


Fig. 595.—Solitary Vesicular Gland of the Small Intestine (from Bœhm). $\frac{10}{1}$

The lighter part of the figure represents the elevation produced by the gland; on this a few villi are seen, and on the surrounding surface of the mucous membrane numerous villi and crypts of Lieberkühn.

Brunner's glands are small rounded compound glands, first pointed out by Brunner, which exist in the duodenum, where they are most numerous at the upper end, in general occupying thickly a space of some inches in extent from the pylorus. According to Huschke, a few of them are also found quite at the commencement of the jejunum. They are imbedded in the areolar tunic, and may be exposed by dissecting off the muscular coat from the outside of the intestine. They are true compound racemose glands, consisting of minute lobules, and containing branched ducts, which open upon the inner surface of the intestine. Their secretion is an alkaline mucus, in which there are no formed elements; and it has no digestive action upon coagulated albumen. (Kölliker.)

Vessels and Nerves.—The branches of the mesenteric artery, having reached the attached border of the intestine, pass round its sides, dividing into numerous ramifications and frequently anastomosing at its free border. Most of the larger branches

run immediately beneath the serous tunic; many pierce the muscular coat, supplying it with vessels as they pass, and having entered the submucous areolar

Fig. 596.

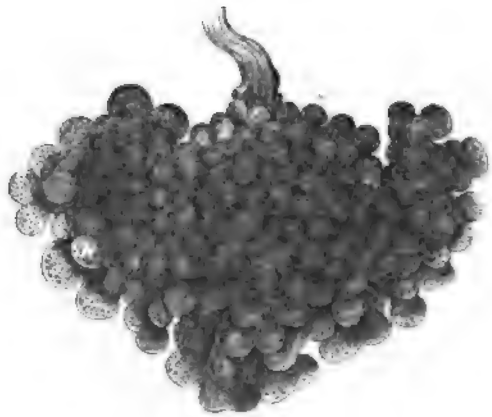


Fig. 596.—ENLARGED VIEW OF ONE OF BRUNNER'S GLANDS FROM THE HUMAN DUODENUM (from Frey).

The main duct is seen superiorly; its branches are elsewhere hidden by the bunches of opaque glandular vesicles.

layer, ramify in it, so as to form a close network, from which still smaller vessels pass on into the mucous coat, and terminate in the capillary network of the folds, villi, and glands of that membrane, which is the most vascular of all the intestinal tissues. The fine capillaries of the muscular coat are arranged in two layers of oblong meshes, which accompany and correspond in direction with the longitudinal and circular muscular fibres. The veins accompany the arteries.

The *absorbents* of the intestine may be conveniently distinguished as those of the mucous membrane and those of the muscular walls. Those of the mucous membrane form a copious plexus which pervades both the mucous and submucous layers, the largest vessels being those which are in the latter layer; but there is not, in the human subject at least, the same distinct division into two strata which has been found in the stomach (Teichmann). With regard to the absorbents of the muscular walls, it has been stated in a former part of this work (p. 491) that according to the concurrent accounts of the various investigators of this subject, the absorbents of the intestine are in two strata, viz. those of the submucous layer already mentioned, and a subserous set, following principally a longitudinal direction beneath the peritoneum, and having only an interrupted communication with the other through intervening trunks; but more recently, a paper by Auerbach has appeared, in which it is stated as the result of transparent injections, that the only truly subperitoneal plexus which exists is confined to a strip in the immediate neighbourhood of the mesentery; that the longitudinal plexus seen by previous observers is really situated between the circular and longitudinal muscular coats; and that besides this, there are likewise copious and close minute capillary plexuses, threading the whole thickness of the muscular walls, in complete continuity with the mucous absorbents, and throwing their contents into those larger vessels the position of which had been misunderstood. To the whole of this series of absorbents Auerbach gives the name of "interlaminar plexus." (Virchow's Archiv., vol. xxxiii., p. 340.)

The *nerves* of the small intestine are chiefly derived from the superior mesenteric plexus (see p. 702). This plexus is formed superiorly by nervous branches, of which those in the middle come from the cœliac plexus, and the lateral ones proceed directly from the semilunar ganglion. The plexus and plexiform branches into which it divides cling at first very closely to the larger divisions of the superior mesenteric artery, especially on their anterior surface, and, dividing similarly with the ramifications of the arteries, the branches of the nerves, retaining still a wide plexiform arrangement, pass onwards to the different parts of the intestine between the two folds of the mesentery, and finally, separating somewhat from the blood-vessels, reach the intestine in very numerous branches.

In regard to the nervous distribution in the coats of the intestine, two recent discoveries of considerable interest have been made. One of them, for which we are indebted to Auerbach, consists in the observation of a peculiar nervous plexus, rich

in ganglion cells, which is situated between the circular and longitudinal muscular fibres of the intestine, and to which he has therefore given the name of "plexus myentericus." For the other observation we are indebted to Meissner, who has dis-

Fig. 597 A.

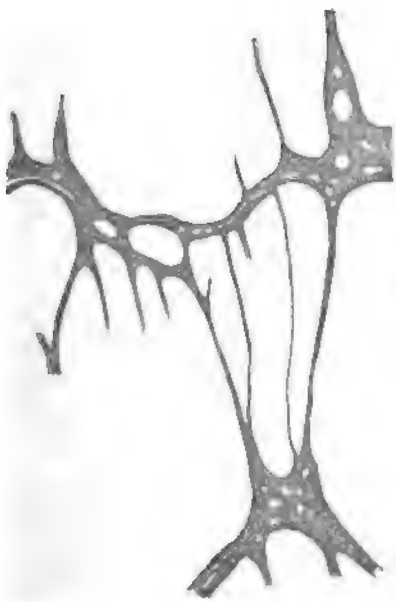


Fig. 597 B.

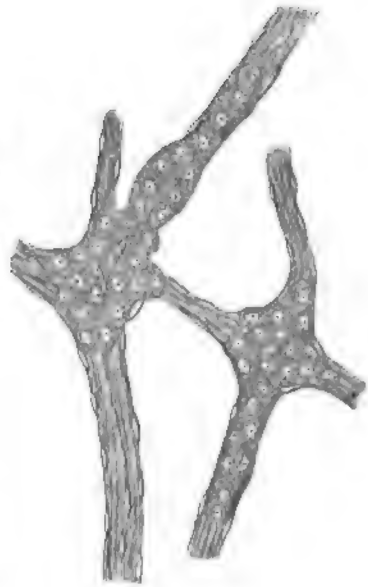


Fig. 597 A. — NERVOUS PLEXUS OF AUERBACH, FROM THE MUSCULAR COAT OF A CHILD'S INTESTINE (from Kölliker). $\frac{30}{1}$

The drawing represents three perforated ganglionic masses united by several nervous cords, of which the thickest is also perforated, forming the "plexus myentericus."

Fig. 597 B.—SMALL PORTION OF MEISSNER'S SUBMUCOUS NERVOUS PLEXUS FROM THE INTESTINE OF A CHILD (from Kölliker). $\frac{350}{1}$

Two ganglia are represented, of which the cells are seen spreading into the nerve-twigs connected with the ganglia: the fusiform particles in the nerve-twigs are small connective-tissue corpuscles.

covered a second richly gangliated plexus of nerves situated in the submucous layer, and which is found to communicate freely with the plexus myentericus of Auerbach by means of the larger branches. Both plexuses extend through the whole length of the intestine, from the pylorus to the anus. (Kölliker, Op. cit., pp. 430 and 432.)

THE LARGE INTESTINE.

The large intestine extends from the termination of the ileum to the anus. It is divided into the cæcum (including the vermiform appendix), the colon, and the rectum; and the colon is again subdivided, according to its direction, into four parts, called the ascending, transverse, and descending colon, and the sigmoid flexure.

The length of the large intestine is usually about five or six feet; being about one-fifth of the whole length of the intestinal canal. Its diameter,

which greatly exceeds that of the small intestine, varies at different points from two inches and a half to about one inch and a half. It diminishes gradually from its commencement at the cæcum to its termination at the anus; excepting that there is a well-marked dilatation of the rectum just above its lower end.

In outward form, the greater part of the large intestine differs remarkably from the small intestine; for, instead of constituting an even cylindrical tube, its surface is thrown into numerous sacculi, marked off from each other by intervening constrictions, and arranged in three longitudinal rows, separated by three strong flat bands of longitudinal muscular fibres. This sacculated structure is not found in the rectum.

For the sake of convenience the description of the rectum will be reserved till that of the rest of the great intestine is completed.

The Cæcum. The intestinum cæcum, or caput cæcum coli, is that part of the large intestine which is situated below the entrance of the ileum. Its length is about two inches and a half, and its diameter nearly the same: it is the widest part of the large intestine.

The cæcum is situated in the right iliac fossa, immediately behind the anterior wall of the abdomen. It is covered by the peritoneum in front, below, and at the sides: but behind it is usually destitute of peritoneal covering, and is attached by areolar tissue to the fascia covering the right iliacus muscle. In this case the cæcum is comparatively fixed; but in other instances the peritoneum surrounds it almost entirely, and forms a duplicature behind it, called *meso-cæcum*.

Proceeding from the inner and back part of the cæcum, at its lower end, is a narrow, round, and tapering portion of the intestine, named the *appendix cæci*, or *appendix vermiformis*. The width of this process is usually about that of a large quill or rather more, and its length varies from three to six inches, these dimensions differing much in different cases. Its general direction is upwards and inwards behind the cæcum; and after describing a few slight turns it ends in a blunt point. It is retained in its position by a small fold of peritoneum, which forms its mesentery. The cæcal appendix is hollow as far as its extremity: and its cavity communicates with that of the cæcum by a small orifice, sometimes guarded by a valvular fold of mucous membrane.

This appendix is peculiar, as far as is known, to man and certain of the higher apes, and to the wombat; but in some animals, as in the rabbit and hare, the distal part of the cæcum, being diminished in diameter and highly glandular, may represent a condition of the appendix.

Ileo-cæcal or *ileo-colic valve.*—The lower part of the small intestine, ascending from left to right, and from before backwards, enters the commencement of the large intestine, with a considerable degree of obliquity, about two inches and a half from the bottom of the cæcum, and opposite the junction of the latter with the ascending colon. The opening leading from the ileum into the large intestine is guarded by a valve composed of two segments or folds. This is the *ileo-cæcal* or *ileo-colic valve:* it is also called the valve of Bauhin and the valve of Tulpius, though Fallopius had described it before either of those anatomists.

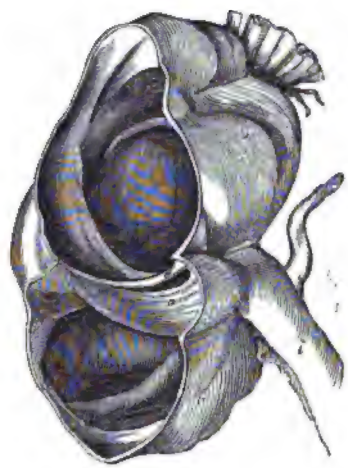
The entrance between the two segments of the valve is a narrow elongated aperture, lying nearly transverse to the direction of the great intestine. The anterior end of this aperture, which is turned forwards and slightly to the left, is rounded, but the posterior end is narrow and pointed. It is bounded above and below by two prominent semilunar folds, which project

inwards towards the cæcum and colon. The lower fold is the larger of the two; the upper is placed more horizontally. At each end of the aperture these folds coalesce, and are then prolonged as a single ridge

Fig. 598.—View of the Ileo-colic Valve from the Large Intestine. ½

The figure shows the lowest part of the ileum, *i*, joining the cæcum, *c*, and the ascending colon, *o*, which have been opened anteriorly so as to display the ileo-colic valve; *a*, the lower, and *e*, the upper segment of the valve.

Fig. 598.



for a short distance round the cavity of the intestine, forming the *fræna* or *retinacula* of the valve. The opposed surfaces of the marginal folds which look towards the ileum, and are continuous with its mucous surface, are covered like it with villi; while their other surfaces, turned toward the large intestine, are smooth and destitute of villi. When the cæcum is distended, the fræna of the valve are stretched, and the marginal folds brought into apposition, so as completely to close the aperture and prevent any reflux into the ileum, while at the same time no hindrance is offered to the passage of additional matters from thence into the great intestine.

Each segment of the valve consists of two layers of mucous membrane, continuous with each other along the free margin, and including between them, besides the submucous areolar tissue, a number of muscular fibres, continued from the circular fibres of the ileum and from those of the large intestine also. The longitudinal muscular fibres, and the peritoneal coat take no part in the formation of the valve, but are stretched across it uninterruptedly from one intestine to the other.

The ascending colon situated in the right lumbar and hypochondriac regions commencing at the cæcum opposite to the ileo-cæcal valve, ascends vertically to the under surface of the liver, near the gall-bladder, where it proceeds forwards and then turns abruptly to the left, forming what is named the *hepatic* flexure of the colon. The ascending colon is smaller than the cæcum, but larger than the transverse colon. It is overlaid in front by some convolutions of the ileum, and is bound down firmly by the peritoneum, which passes over its anterior surface and its sides, and generally leaves an interval in which its posterior surface is connected by areolar tissue with the fascia covering the quadratus lumborum muscle, and with the front of the right kidney. In some cases, however, the peritoneum passes nearly round it, and forms a distinct though very short right meso-colon.

The transverse colon passes across from the right hypochondrium, through the upper part of the umbilical region, into the left hypochondrium. Sometimes it is found as low as the umbilicus or even lower. At each extremity it is situated deeply towards the back part of the abdominal cavity, but in the middle it curves forwards, and lies close to the anterior wall of the abdomen. Hence it describes an arch, the concavity of which is

turned towards the vertebral column; and it has accordingly been named the *arch* of the colon.

Above, the transverse colon is in contact with the under surface of the liver, the gall-bladder, the great curvature of the stomach, and the lower end of the spleen. Below it are the convolutions of the small intestine, the third portion of the duodenum being behind it. It is invested behind by the general peritoneum, and in front it adheres to the sac of the omentum.

THE DESCENDING COLON is continuous with the left extremity of the transverse colon by a sudden bend named the *splenic flexure*. It then descends almost perpendicularly through the left hypochondriac and lumbar regions to the left iliac fossa, where it ends in the sigmoid flexure. The peritoneum affords a covering to it only in front and at the sides, whilst behind, it is connected by areolar tissue to the left crus of the diaphragm, the quadratus lumborum and the left kidney. It is usually concealed behind some convolutions of the jejunum.

THE SIGMOID FLEXURE of the colon, situated in the left iliac fossa, consists of a double bending of the intestine upon itself in the form of the letter S, immediately before it becomes continuous with the rectum at the margin of the pelvis opposite to the left sacro-iliac articulation. It is attached by a distinct meso-colon to the iliac fossa, and is very movable. It is placed immediately behind the anterior parietes, or is concealed only by a few turns of the small inestine. The sigmoid flexure is the narrowest part of the colon.

Structure of the large intestine.—The walls of the large intestine consist of four coats, like those of the stomach and small intestine, namely, the serous, muscular, areolar, and mucous.

The *serous* and *areolar* coats require no further description here.

The *muscular* coat, like that of the other parts of the intestinal canal, consists of external longitudinal and internal circular fibres. The *longitudinal* fibres, though found in a certain amount all around the intestine, are, in the cæcum and colon, principally collected into three remarkable flat longitudinal bands. These bands, sometimes called the ligaments of the colon, are about half an

Fig. 599.

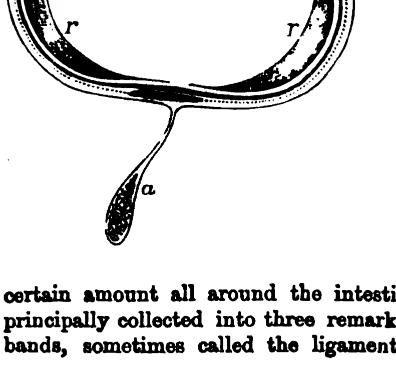


Fig. 599.—OUTLINE SKETCH OF A SECTION OF THE ASCENDING COLON. ⅔

s, the serous or peritoneal covering; *s'*, *s'*, reflection of this at the attached border forming a short wide mesentery, between the folds of which the blood-vessels are seen passing to the colon; *a*, one of the appendices epiploicæ hanging from the inner border; *lm*, indicates at the free border one of the three bands formed by the thickening of the longitudinal muscular coat; the dotted line continued from the margins of these bands represents the remainder of the longitudinal muscular coat, and the thick line within it, marked *c m*, represents the circular muscular layer; *m*, the mucous membrane at the flattened part; *r*, the cresentic bands or indentations which divide the sacculi.

inch wide, and half a line thick; they commence upon the extremity of the cæcum, at the attachment of the vermiform appendix, and may be traced along the whole length of the colon as far as the commencement of the rectum, where they spread out, so as to surround that part of the intestinal tube with a continuous layer of longitudinal muscular fibres. One of these bands, named the *posterior*, is placed along the attached border of the intestine; another corresponds with its *anterior* border, and, in the transverse colon, is situated at the attachment of the great omentum; whilst the third band (*lateral*) is found along the free side of the intestine, that is, on the inner border of the ascending and descending colon, and on the under border of the transverse colon. It is along the course of this third band that the appendices epiploicæ are most of them attached. Measured from end to end, these three bands are shorter than the intervening parts of the tube; and the latter are thus thrown into the sacculi already mentioned: accordingly, when the bands are removed by dissection, the sacculi are entirely effaced, and the colon, elongating considerably, assumes the cylindrical form. The transverse constrictions seen on the exterior of the intestine, between the sacculi, appear on the inside of the intestine as sharp ridges separating the cells, and are composed of all its coats. In the vermiform appendix the longitudinal muscular fibres constitute a uniform layer.

The *circular* muscular fibres form only a thin layer over the general surface of the cæcum and colon, but are accumulated in larger numbers between the sacculi. In the rectum, especially towards its lower part, the circular fibres form a very thick and powerful muscular layer.

Fig. 600.

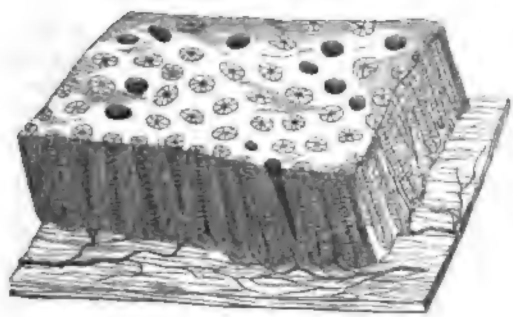


Fig. 600.—Semi-diagrammatic View of a Small Portion of the Mucous Membrane of the Colon. $\frac{20}{1}$

A small portion of the mucous membrane cut perpendicularly at the edges is shown in perspective; on the surface are seen the orifices of the crypts of Lieberkühn or tubular glands, the most of them lined by their columnar epithelium, a few divested of it and thus appearing larger; along the sides the tubular glands are seen more or less equally divided by the section; these are resting on a wider portion of the submucous tissue, from which the blood-vessels are in a part represented as passing into the spaces between the glands.

The *mucous* membrane differs from the lining membrane of the small intestine in having no folds, like the valvulæ conniventes, as also in being quite smooth and destitute of villi. Viewed with a lens, its surface is seen

to be marked all over by the orifices of numerous tubuli, resembling those of the stomach and the crypts of the small intestine. These follicles are arranged perpendicularly to the surface of the membrane; they are longer and more numerous, and are placed more closely together and at more regular intervals than those of the small intestine. Their orifices are circular, and, when widened by the loss of their epithelial lining, they give the mucous membrane a cribriform aspect.

Besides these, there are scattered over the surface of the whole large intestine numerous *closed follicles*, similar to the solitary glands of the small intestine, but marked by a depression passing down to them between the surrounding tubules (Kölliker). They are most abundant in the cæcum and in its vermiform appendix; being placed closely all over the latter.

The epithelium, which covers the general surface of the mucous membrane, and lines the tubuli and follicles, is of the columnar kind.

Vessels and Nerves.—In the great intestine of the rabbit, Frey figures the same arrangement of capillary plexuses and venous radicles as has been described in the stomach. He finds also in the rabbit clavate lacteals in rudimentary villi. (Zeitsch. f. wissensch. Zoologie, vol. xiii.); but Teichmann's injections in the human subject show no absorbents more superficial than the bases of the tubular follicles.

Nervous plexuses similar to those of the small intestine have also been found in the walls of the large intestine.

THE RECTUM.

The lowest portion of the large intestine, named the *rectum*, extends from the sigmoid flexure of the colon to the anus, and is situated entirely within the true pelvis, in its back part.

Commencing opposite to the left sacro-iliac articulation, it is directed at first obliquely downwards, and from left to right, to gain the middle line of the sacrum. It then changes its direction, and curves forwards in front of the lower part of the sacrum and the coccyx, and behind the bladder, vesiculæ seminales and prostate in the male, and at the back of the cervix uteri and vagina in the female. Opposite to the prostate it makes another turn, and inclines downwards and backwards to reach the anus. The name rectum, therefore, so called from its original description being derived from animals, is far from being straight in the human subject. Seen from the front, the upper part of the rectum presents a lateral inclination from the left to the median line of the pelvis, sometimes passing beyond the middle to the right; and when viewed from the side it offers two curves, one corresponding with the hollow front of the sacrum and coccyx, and the other at the lower end of the bowel, forming a shorter turn in the opposite direction.

Unlike the rest of the large intestine, the rectum is not sacculated, but is smooth and cylindrical; and it has no separate longitudinal bands upon it. It is about six or eight inches in length; and is rather narrower than the sigmoid flexure at its upper end, but becomes dilated into a large ampulla or reservoir, immediately above the anus.

The upper part of the rectum is in contact in front with the back of the bladder (or uterus in the female), unless some convolutions of the small intestine happen to descend into the interval between them. This part is surrounded by peritoneum, which attaches it behind to the sacrum by a duplicature named the meso-rectum. Lower down, the peritoneum covers the intestine in front and at the sides, and at last its anterior surface only;

still lower, it quits the intestine altogether, and is reflected forwards to ascend upon the back of the bladder in the male, and of the upper part of the vagina and the uterus in the female. In passing from the rectum to the bladder, the peritoneum forms a cul-de-sac, or recto-vesical pouch, which extends downwards between the intestine and the bladder to within an inch or more from the base of the prostate, and is bounded on the sides by two lunated folds of the serous membrane.

Fig. 601.

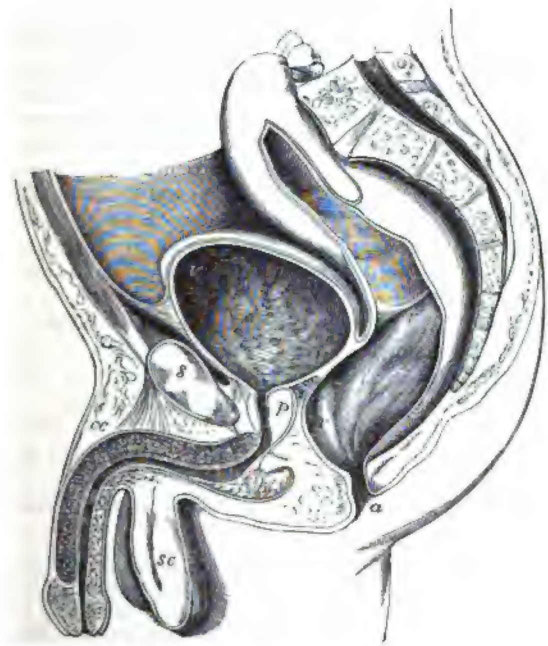


Fig. 601.—VERTICAL SECTION OF THE PELVIS AND ITS VISCERA IN THE MALE (from Houston). ½

This figure is introduced to illustrate the form, position, and relations of the rectum; it also shows the bladder and urethra with the pelvic inflection of the peritoneum over these viscera: *r*, *r*, *r*, the upper and middle parts of the rectum, and at the middle letter the fold separating the two; *r a*, the lower or anal portion; *v*, the upper part of the urinary bladder; *v′*, the base at the place where it rests more immediately on the rectum; *p*, the prostate gland and prostatic portion of the urethra; *b*, the bulb; *cc*, the corpus cavernosum penis and suspensory ligament; *s c*, the divided tissue within the scrotum.

Below the point where the peritoneum ceases to cover it, the rectum is connected to surrounding parts by areolar tissue, which is mostly loaded with fat. In this way it is attached behind to the front of the sacrum and the coccyx, and at the sides to the coccygei and levatores ani muscles. In front, it is in immediate connection with a triangular portion of the base of the bladder; on each side of this, with the vesiculæ seminales; and farther forwards, with the under surface of the prostate. Below the prostate, where the rectum turns downwards to reach the anus, it becomes invested by the fibres of the internal sphincter, and embraced by the levatores ani

to be marked all over by the orifices of numerous tubuli, resembling those of the stomach and the crypts of the small intestine. These follicles are arranged perpendicularly to the surface of the membrane; they are longer and more numerous, and are placed more closely together and at more regular intervals than those of the small intestine. Their orifices are circular, and, when widened by the loss of their epithelial lining, they give the mucous membrane a cribriform aspect.

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Commencing opposite to the left sacro-iliac articulation, it is directed at first obliquely downwards, and from left to right, to gain the middle line of the sacrum. It then changes its direction, and curves forwards in front of the lower part of the sacrum and the coccyx, and behind the bladder, vesiculæ seminales and prostate in the male, and at the back of the cervix uteri and vagina in the female. Opposite to the prostate it makes another turn, and inclines downwards and backwards to reach the anus. The *intestinum rectum*, therefore, so called from its original description being derived from animals, is far from being straight in the human subject. Seen from the front, the upper part of the rectum presents a lateral inclination from the left to the median line of the pelvis, sometimes passing beyond the middle to the right; and when viewed from the side it offers two curves, one corresponding with the hollow front of the sacrum and coccyx, and the other at the lower end of the bowel, forming a shorter turn in the opposite direction.

Unlike the rest of the large intestine, the rectum is not sacculated, but is smooth and cylindrical; and it has no separate longitudinal bands upon it. It is about six or eight inches in length; and is rather narrower than the sigmoid flexure at its upper end, but becomes dilated into a large ampulla or reservoir, immediately above the anus.

The upper part of the rectum is in contact in front with the back of the bladder (or uterus in the female), unless some convolutions of the small intestine happen to descend into the interval between them. This part is surrounded by peritoneum, which attaches it behind to the sacrum by a duplicature named the *meso-rectum*. Lower down, the peritoneum covers the intestine in front and at the sides, and at last its anterior surface only;

still lower, it quits the intestine altogether, and is reflected forwards to ascend upon the back of the bladder in the male, and of the upper part of the vagina and the uterus in the female. In passing from the rectum to the bladder, the peritoneum forms a cul-de-sac, or recto-vesical pouch, which extends downwards between the intestine and the bladder to within an inch or more from the base of the prostate, and is bounded on the sides by two lunated folds of the serous membrane.

Fig. 601.

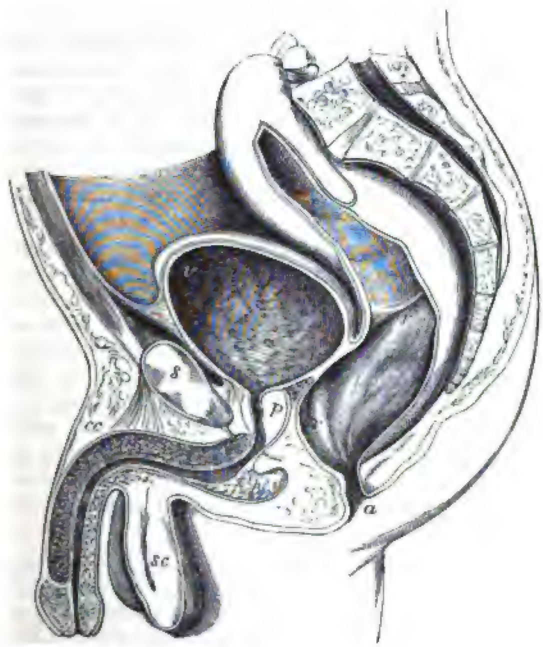

Fig. 601.—Vertical Section of the Pelvis and its Viscera in the Male (from Houston). ½

This figure is introduced to illustrate the form, position, and relations of the rectum; it also shows the bladder and urethra with the pelvic inflection of the peritoneum over these viscera: *r*, *r*, *r*, the upper and middle parts of the rectum, and at the middle letter the fold separating the two; *r a*, the lower or anal portion; *v*, the upper part of the urinary bladder; *v′*, the base at the place where it rests more immediately on the rectum; *p*, the prostate gland and prostatic portion of the urethra; *b*, the bulb; *cc*, the corpus cavernosum penis and suspensory ligament; *s c*, the divided tissue within the scrotum.

Below the point where the peritoneum ceases to cover it, the rectum is connected to surrounding parts by areolar tissue, which is mostly loaded with fat. In this way it is attached behind to the front of the sacrum and the coccyx, and at the sides to the coccygei and levatores ani muscles. In front, it is in immediate connection with a triangular portion of the base of the bladder; on each side of this, with the vesiculæ seminales; and farther forwards, with the under surface of the prostate. Below the prostate, where the rectum turns downwards to reach the anus, it becomes invested by the fibres of the internal sphincter, and embraced by the levatores ani

to be marked all over by the orifices of numerous tubuli, resembling those of the stomach and the crypts of the small intestine. These follicles are arranged perpendicularly to the surface of the membrane; they are longer and more numerous, and are placed more closely together and at more regular intervals than those of the small intestine. Their orifices are circular, and, when widened by the loss of their epithelial lining, they give the mucous membrane a cribriform aspect.

Besides these, there are scattered over the surface of the whole large intestine numerous *closed follicles*, similar to the solitary glands of the small intestine, but marked by a depression passing down to them between the surrounding tubules (Kölliker). They are most abundant in the cæcum and in its vermiform appendix; being placed closely all over the latter.

The epithelium, which covers the general surface of the mucous membrane, and lines the tubuli and follicles, is of the columnar kind.

Vessels and Nerves.—In the great intestine of the rabbit, Frey figures the same arrangement of capillary plexuses and venous radicles as has been described in the stomach. He finds also in the rabbit clavate lacteals in rudimentary villi. (Zeitsch. f. Wissensch. Zoologie, vol. xii.); but Teichmann's injections in the human subject show no absorbents more superficial than the bases of the tubular follicles.

Nervous plexuses similar to those of the small intestine have also been found in the walls of the large intestine.

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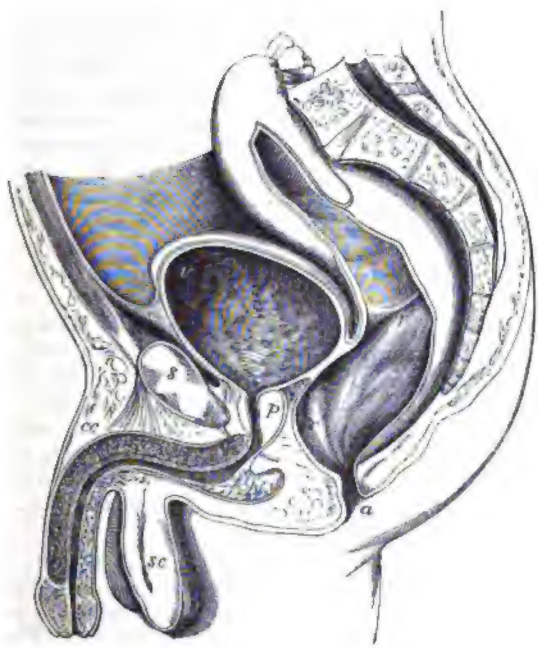

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muscles, by which it is supported. Lastly, at its termination it is surrounded by the external sphincter ani muscle. In the female, the lower portion of the rectum is firmly connected with the back of the vagina.

Structure.—The rectum differs in some respects from the rest of the large intestine, in the structure of both its muscular and its mucous coats.

The muscular coat is very thick: the external or longitudinal fibres form a uniform layer round it, and cease near the lower end of the intestine; the internal or circular fibres, on the contrary, become more numerous in that situation, where they form what is named the internal sphincter muscle. The longitudinal fibres are paler than the circular fibres, but both layers become darker and redder towards the termination of the bowel.

The mucous membrane of the rectum is thicker, redder, and more vascular than that of the colon; and it moves freely upon the muscular coats; —in that respect resembling the lining membrane of the œsophagus. It presents numerous folds of different sizes, and running in various directions, nearly all of which are effaced by the distension of the bowel. Near the anus these folds are principally longitudinal, and seem to depend on the contraction of the sphincter muscles outside the loosely connected mucous membrane. The larger of these folds were named by Morgagni the *columns* of the rectum (*columnæ recti*). Treitz states that these columns consist of longitudinal muscular fibres, which terminate both superiorly and inferiorly in elastic tissue. Higher up in the intestine, the chief folds are transverse or oblique. Three prominent folds, larger than the rest, being half an inch or more in depth, and having an oblique direction in the interior of the rectum, have been pointed out specially by Houston. One of these projects backwards from the upper and fore part of the rectum, opposite the prostate gland; another is placed higher up, at the side of the bowel; and the third still higher. From the position and projection of these folds, they may more or less impede the introduction of instruments. (Houston, Dublin Hospital Reports, vol. v.)

Vessels and Nerves.—The *arteries* of the rectum spring from three sources, viz. the superior hæmorrhoidal branches from the inferior mesenteric; the middle hæmorrhoidal branches from the internal iliac directly or indirectly; and, lastly, the external or inferior hæmorrhoidal branch from the pudic artery. The arrangement of the vessels is not the same throughout the rectum. Over the greater part the arteries penetrate the muscular coat at short intervals, and, at once dividing into small branches, form a network by their communication. Towards the lower end, for four or five inches, the arrangement differs. Here the vessels, having penetrated the muscular coat at different heights, assume a longitudinal direction, passing in parallel lines towards the end of the bowel. In their progress downwards they communicate with one another at intervals, and they are very freely connected near the orifice, where all the arteries join by transverse branches of considerable size. (Quain, Diseases of the Rectum).

The *veins* are very numerous, and form a complex interlacement resembling that of the arteries just described, and named the hæmorrhoidal plexus. After following a longitudinal course upwards similar to that of the arteries which they accompany, they end partly in the internal iliac vein by branches which accompany the middle hæmorrhoidal artery, and partly in the inferior mesenteric vein. Hence, the blood from the rectum is returned in part into the vena cava, and in part into the portal system. (See Fig. 325.)

The *lymphatics* enter some glands placed in the hollow of the sacrum, or those of the lumbar series.

The *nerves* are very numerous, and are derived from both the cerebro-spinal and the sympathetic systems. The former consist of branches derived from the sacral plexus; and the latter, of offsets from the inferior mesenteric and hypogastric plexuses.

THE ANUS AND ITS MUSCLES.

The *anus*, or lower opening of the alimentary canal, is a dilatable orifice, surrounded internally by the mucous membrane, and externally by the skin, which two structures here become continuous with and pass into each other. The skin around the borders of the anus, which is thrown into wrinkles or folds during the closed state of the orifice, is covered with numerous sensitive papillæ, and is provided with hairs and sebaceous follicles.

The lower end of the rectum and the margin of the anus are, moreover, embraced by certain muscles, which serve to support the bowel, and to close its anal orifice. These muscles, proceeding from within outwards, are, the internal sphincter, the levatores ani, the coccygei, and the external sphincter. The three last muscles have already been described (pp. 262, 263).

The *internal sphincter* muscle (sphincter ani internus) is a muscular ring or rather belt, surrounding the lower part of the rectum, an inch above the anus, and extending over about half an inch of the intestine. It is two lines thick, and is paler than the external sphincter. Its fibres are continuous above with the circular muscular fibres of the rectum, and, indeed, it consists merely of those fibres more numerously developed than elsewhere, and prolonged farther down than the external longitudinal fibres.

Kohlrausch describes a thin stratum of fibres between the mucous membrane and the internal sphincter, these fibres having a longitudinal direction. Henle thinks this is nothing more than the stratum of fibres belonging to the proper mucous coat; but Kohlrausch gives it a distinct name, the sustentator tunicæ mucosæ. (Kohlrausch, Anat. und Phys. d. Beckenorgane, Leipzig. 1854.)

DEVELOPMENT OF THE ALIMENTARY CANAL AND PERITONEAL CAVITY.

It has been already casually stated (p. 15) that the epithelial lining of the alimentary canal is derived from the deepest of the three layers into which the germinal membrane divides, while the rest of its walls are derived from a part of the middle layer. To make this clear, it is necessary to state that while those parts of the middle layer of the embryo which lie next to the chorda dorsalis, form the dorsal plates from which the bones, nerves, and muscles of the trunk are derived, the lateral parts lying beyond form, as described by Remak, the *visceral plates*, which on each side divide into a deep and a superficial part, and, at the same time growing inwards, unite together on the ventral aspect of the chorda dorsalis, forming by their union the *mesial plate*. The superficial divisions of the two visceral plates, remaining in contact with the outer epithelial layer of the embryo, form the cutis; the deep division is the *musculo-intestinal layer*, which forms the walls of the alimentary canal, with the exception of its epithelial lining; and the space between the superficial and deep divisions is the common pleuro-peritoneal cavity, from which the pleural and peritoneal cavities become separated in a subsequent stage of development.

The alimentary canal commences in the form of a groove which opens towards the yelk-cavity of the ovum; and the internal epithelial and musculo-intestinal layers in which this groove is formed, are continued round the yelk, constituting the walls of the vitelline sac. The open groove is soon changed into a tube at each end, but is left open in the middle upon the ventral aspect, and communicates at first by a wide aperture, but later by means of a tube, named the omphalo-enteric canal or vitelline duct, with the vitelline sac. This duct is soon obliterated, and the vitelline sac becomes the umbilical vesicle, which is thereafter connected for a time with the embryo only by a slender elongated pedicle, which enters at the umbilicus and is accompanied by the omphalo-mesenteric vessels; this pedicle is finally atrophied and disappears.

The *alimentary canal*, when it first assumes the tubular form, constitutes a simple straight cylinder closed at each end, and placed along the front of the vertebral column, to which it is closely attached at each extremity, whilst in the middle of its course it is connected to the rest of the embryo by a median membranous fold, or rudimental

Fig. 602.

A.

B.

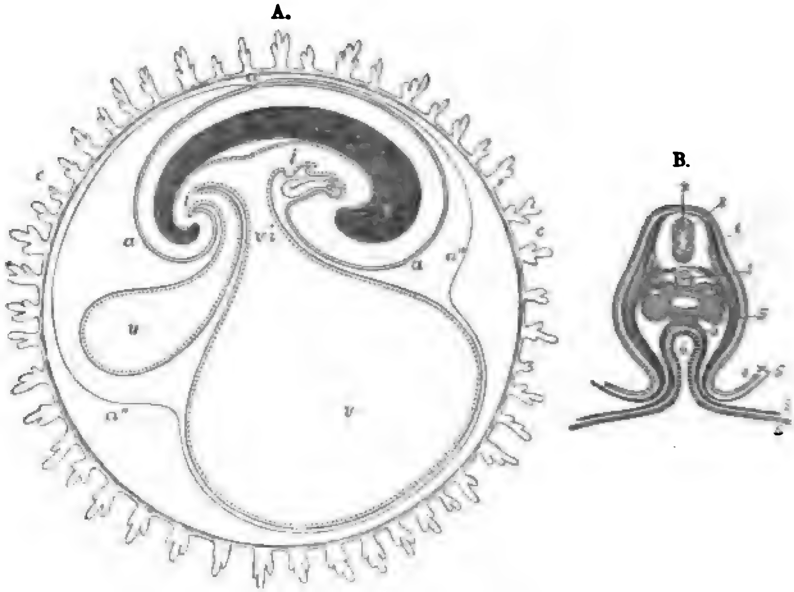


Fig. 602, A.—Diagrammatic Section showing the Relation in a Mammal and in Man between the Primitive Alimentary Canal and the Membranes of the Ovum.

The stage represented in this diagram corresponds to that of the fifteenth or seventeenth day in the human embryo, previous to the expansion of the allantois : *c*, the villous chorion ; *a*, the amnion ; *a'*, the place of convergence of the amnion and reflection of the false amnion *a'' a''*, or outer or corneous layer ; *e*, the head and trunk of the embryo, comprising the primitive vertebræ and cerebro-spinal axis ; *i*, *i*, the simple alimentary canal in its upper and lower portions ; *v*, the yolk-sac or umbilical vesicle ; *v i*, the vitello-intestinal opening ; *u*, the allantois connected by a pedicle with the anal portion of the alimentary canal.

Fig. 602, B.—Transverse Section of the Body of an Embryo, with a Part of the adjacent Membranes, showing the Relation of the Alimentary Cavity to the Layers of the Germinal Membrane (from Remak and Kölliker). $\frac{15}{1}$

1, chorda dorsalis ; 2, 3, spinal marrow ; 4, cuticular layer, and within it the primordial vertebral segments ; 5, the ventral or visceral plates, consisting of the cuticular layer and the outer lamina of the middle germinal layer, passing at 4 × 5 from the umbilicus into the amnion ; 5', within the embryo, is placed in the peritoneal cavity, below one of the Wolffian bodies and close to the musculo-intestinal lamina ; 6, cavity of the intestine lined by the epithelial or epithelio-glandular layer, which, along with the musculo-intestinal, is continued by the ductus vitello-intestinalis into the yolk-sac, 5' 6.

mesentery. Soon, however, the intestine, growing in length, advances from the spine, and forms a simple loop in the middle of the body, with a straight portion at its upper and lower end, and at the same time becomes slightly dilated in the part destined to form the stomach. The middle of the loop is connected with the umbilical vesicle by the pedicle, and also by the omphalo-mesenteric vessels. The upper extremity of the primitive alimentary tube reaches to the base of the skull and forms the œsophagus and pharynx ; but the mouth is developed by depression of the outer surface of the embryo, above the first branchial arch, and together with the tongue is at first separated from the throat by a partition, which soon gives way. In like manner, the anal orifice does not exist at first, but is formed by invagination of the outer surface, and the opening of a communication between it and the intestine.

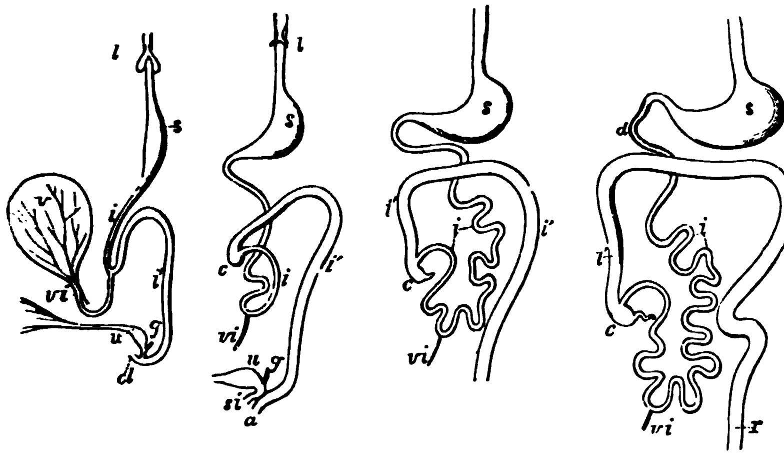


Fig. 603.—OUTLINES OF THE FORM AND POSITION OF THE ALIMENTARY CANAL IN SUCCESSIVE STAGES OF ITS DEVELOPMENT.

A, alimentary canal, &c., in an embryo of four weeks; B, at six weeks; C, at eight weeks; D, at ten weeks; *l*, the primitive lungs connected with the pharynx; *s*, the stomach; *d*, duodenum; *i*, the small intestine; *i'*, the large; *c*, the cæcum and vermiform appendage; *r*, the rectum; *cl*, in A, the cloaca; *a*, in B, the anus distinct from *si*, the sinus uro-genitalis; *v*, the yolk sac; *vi*, the vitello-intestinal duct; *u*, the urinary bladder and urachus leading to the allantois; *g*, the genital ducts.

The dilated portion of the tube which forms the stomach turns over on its right side, so that the border, which is connected to the vertebral column by the membranous fold (or true mesogastrium) comes to be turned to the left,—the position of the tube being still vertical, like the stomach of some animals. By degrees it becomes more dilated, chiefly on what is now the left border but subsequently the great curvature, and assumes first an oblique and finally a transverse position, carrying with it the mesogastrium, from which the great omentum is afterwards produced. A slight indication of the pylorus is seen at the third month. Upon the surface of the part of the canal which immediately succeeds the stomach, and which forms the duodenum, the rudiments of the liver, pancreas, and spleen are simultaneously deposited: in connection with the two former, protrusions of the mucous membrane grow into their blastemic mass and form the commencement of their principal ducts.

The place of distinction between the small and the large intestine, which is soon indicated by the protrusion of the cæcum, is at a point just below the apex or middle of the simple loop already mentioned. As the *small* intestine grows, the part below the duodenum forms a coil which at first lies in the commencing umbilical cord, but retires again into the abdomen about the tenth week; afterwards it continues to elongate, and its convolutions become more and more numerous.

The *large* intestine is at first less in calibre than the small. In the early embryo there is at first no cæcum. This part of the bowel gradually grows out from the rest, and in the first instance forms a tube of uniform calibre, without any appearance of the vermiform appendix: subsequently the lower part of the tube ceases to grow in the same proportion, and becomes the appendix, whilst the upper portion continues to be developed with the rest of the intestine. The cæcum now appears as a protrusion a little below the apex of the bend in the primitive intestinal tube, and, together with the commencing colon, and the coil of small intestine, is at first lodged in the wide part of the umbilical cord which is next the body of the embryo. The ileocæcal valve appears at the commencement of the third month. When the coils of intestine and cæcum have retired from the umbilicus into the abdomen, the colon is at first entirely to the left of the convolutions of the small intestines, but subse-

quently the first part of the large intestine, together with the meso-colon, crosses over the upper part of the small intestine, at the junction of the duodenum and jejunum. The cæcum and transverse colon are then found just below the liver; finally, the cæcum descends to the right iliac fossa, and at the fourth or fifth month the parts are in the same position as in the adult. At first, villous processes or folds of various lengths are formed throughout the whole canal. After a time these disappear in the stomach and large intestine, but remain persistent in the intermediate portions of the tube. According to Meckel, the villous processes are formed from larger folds, which become serrated at the edge and divided into separate villi.

The mode of development of the alimentary canal accounts, in some measure, for the principal complication in the folds of the peritoneum. The stomach being originally straight in form and mesial in position, the small omentum and gastro-phrenic ligament must be regarded as an originally mesial fold with the free edge directed forwards, which afterwards forms the anterior boundary of the foramen of Winslow. Thus the anterior wall of the sac of the omentum, as far as the great curvature of the stomach, may be considered as formed by the right side of a mesial fold, while the peritoneum in front of the stomach belongs to the left side of the same, and a sac of the omentum is a natural consequence of the version and disproportionate growth of the tube between the duodenum and the cardiac orifice of the stomach. It is obvious that the view of the omental sac, according to which its posterior layers are held to return to the duodenum and posterior wall of the body before proceeding to form the transverse meso-colon (p. 829) is more consistent with the phenomena of development now described, than that which would make them directly enclose the colon. On the other hand, the further elongation of the omental sac and the whole disposition of the peritoneum, with respect to the colon, must be regarded as having taken place after the assumption by the great intestine of its permanent position.

Fig. 603*.

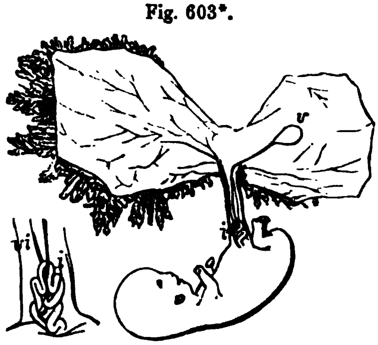


Fig. 603*.—Sketch of the Human Embryo of the Eighth or Ninth Week, showing the Coil of Intestine in the Umbilical Cord.

The amnion and villous chorion have been opened and the embryo drawn aside from them; *v*, the umbilical vesicle or yolk-sac placed between the amnion and chorion, and connected with the coil of intestine, *i*, by a small or almost linear tube; the figure at the side represents the first part of the umbilical cord magnified; *i*, coil of intestine; *v i*, vitello-intestinal duct, alongside of which are seen omphalo-mesenteric blood-vessels.

The occurrence of umbilical hernia in its various degrees may be referred to the persistence of one or other of the fœtal conditions in which a greater or less portion of the intestinal canal is contained in the umbilical cord; and it has been shown that the most common diverticulum of the small intestine is connected with the original opening of the ductus vitello-intestinalis into the ileum (p. 841).

THE LIVER.

The liver is an important glandular organ, very constant in the animal series, being found in all vertebrate, and, in a more or less developed condition, in most invertebrate tribes. It elaborates and secretes the bile, and otherwise acts, in a manner as yet imperfectly understood, as an elaborator and purifier of the blood. In the exercise of this latter function, there is formed in its texture an amyloid substance, very easily converted into sugar.

The liver is the largest gland in the body, and by far the most bulky of the abdominal viscera. It measures about ten or twelve inches transversely

from right to left, between six and seven inches from its posterior to its anterior border, and about three and a half inches from above downwards at its thickest part, which is towards the right and posterior portion of the gland. The average bulk, according to Krause, is eighty-eight cubic inches; according to Beale, one hundred. The ordinary weight in the adult is stated to be between three and four pounds, or more precisely from fifty to sixty ounces avoirdupois.

Fig. 604.

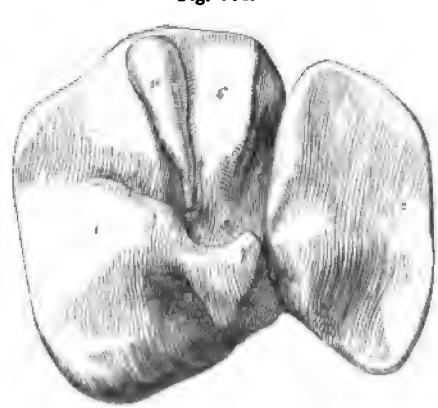


Fig. 604.—SKETCH OF THE UNDER SURFACE OF THE LIVER. ¼

The anterior border is turned upwards, and the blood-vessels and ducts have been removed: 1, the right lobe; 2, the left lobe; 3, 4, the longitudinal fissure; 3, its umbilical part; 4, part containing the ductus venosus; 5, transverse or portal fissure; 6, lobulus quadratus; 7, lobulus Spigelii; 8, lobulus caudatus; 9, fissure or fossa of the vena cava; 10, the gall bladder in its fossa.

According to the facts recorded by Reid, the liver weighed, in 43 cases out of 82, between 48 and 58 ounces in the adult male; and in 17 cases out of 36, its weight in the adult female ranged between 40 and 50 ounces. It is generally estimated to be equal to about 1-36th of the weight of the whole body; but in the fœtus, and in early life, its proportionate weight is greater. (Reid, in Lond. and Edin. Monthly Journal of Med. Science, April, 1843.)

The specific gravity of the liver, according to Krause and others, is between 1·05 and 1·06: in fatty degeneration this is reduced to 1·03, or even less.

The parenchyma of the liver has an acid reaction (Kölliker). Beale gives the following results of his analysis of the liver of a healthy man, who was killed by a fall.

Water		68·58
Solid matters		31·42
Fatty matters	3·82	
Albumen	4·67	
Extractive matters	5·40	
Alkaline salts	1·17	
Vessels, &c. insoluble in water	16·03	
Earthy salts	·33	
		100 00

The liver is a solid organ, of a dull reddish-brown colour, with frequently a dark-purplish tinge along the margin. It has an upper smooth and convex surface, and an under surface which is uneven and concave; the circumference is thick and rounded posteriorly and towards the right extremity, but becomes gradually thinner towards the left and in front, where it forms the sharp anterior and left lateral margins.

The *upper surface* is convex, smooth, and covered with peritoneum. It is marked off into a right portion, large and convex, and a left portion,

smaller and flatter, by the line of attachment of the fold of peritoneum named the falciform ligament.

The *under surface*, looking downwards and backwards, is concave and uneven, invested with peritoneum everywhere except where the gall bladder is adherent to it, and at the portal fissure and fissure of the ductus venosus, which give attachment to the small omentum, the fold of peritoneum which passes round the blood-vessels and ducts of the viscus. On this surface the lobes and fissures of the liver are observed.

The lobes of the liver, five in number, are named the right and the left, the lobe of Spigelius, the caudate or tailed lobe, and the square lobe.

The *right* and *left* lobes are separated from each other on the under surface by the longitudinal fissure, and in front by the interlobular notch: on the convex surface of the liver there is no other indication of a separation between them than the line of attachment of the broad ligament. The right lobe is much larger and thicker than the left, which constitutes only about one-fifth or one-sixth of the entire gland.

The other three lobes are small, and might be said to form parts of the right lobe, on the under surface of which they are situated.

The *lobulus quadratus* is that part which is situated between the gall-bladder and the great longitudinal fissure, and in front of the fissure for the portal vein. Its greatest diameter is from before backwards.

The *lobulus Spigelii*, more prominent and less regular in shape than the quadrate lobe, lies behind the fissure for the portal vein, and is bounded on the right and left by the fissures which contain the inferior vena cava and the remains of the ductus venosus.

The *lobulus caudatus* is a sort of ridge which extends from the base of the Spigelian lobe to the under surface of the right lobe. This, in the natural position of the parts, passes forwards above the foramen of Winslow, the Spigelian lobe itself being situated behind the small omentum, and projecting into the omental sac.

The fissures.—These are likewise five in number, and are seen on the under surface only. They have all been already incidentally referred to.

The *transverse* fissure, or *portal* fissure, is the most important, because it is here that the great vessels and nerves enter, and the hepatic duct passes out. It lies transversely between the lobulus quadratus and lobulus Spigelii, and meets the longitudinal fissure nearly at right angles. At the two extremities of this fissure, the right and left divisions of the hepatic artery and portal vein, together with the nerves and deep lymphatics enter the organ, while the right and left hepatic ducts emerge.

The *longitudinal* fissure, which separates the right and the left lobes of the liver from each other, is divided into two parts by its meeting with the transverse fissure. The anterior part, named the *umbilical* fissure, contains the umbilical vein in the fœtus, and the remnant of that vein in the adult, which then constitutes the round ligament. It is situated between the square lobe and the left lobe of the liver, the substance of which often forms a bridge across the fissure, so as to convert it partially or completely into a canal. The posterior part is named the *fissure* of the *ductus venosus* (fossa ductus venosi); it continues the umbilical fissure backwards between the lobe of Spigelius and the left lobe; and it lodges the ductus venosus in the fœtus, and in the adult a slender cord or ligament into which that vein is converted.

The *fissure* or *fossa* of the *vena cava* is situated at the back part of the liver, between the Spigelian lobe on the left and the right lobe, and is

separated from the transverse fissure by the caudate lobe. It is prolonged upwards in an oblique direction to the posterior border of the liver, and may be said to join behind the Spigelian lobe with the fissure for the ductus venosus. It is at the bottom of this fossa that the blood leaves the liver by the hepatic veins, which end here in the vena cava. The substance of the liver in some cases unites around the vena cava, and encloses that vessel in a canal.

The last remaining fissure, or rather *fossa* (fossa cystis felleæ), is that for the lodgment of the gall-bladder; it is sometimes continued into a slight notch on the anterior margin of the liver.

Two shallow impressions are seen on the under surface of the right lobe; one in front (*impressio colica*), corresponding with the hepatic flexure of the colon; and one behind (*impressio renalis*), corresponding with the right kidney.

The *anterior border* of the liver, a thin, free, and sharp margin, is the most movable part of the gland. Opposite the longitudinal fissure the anterior border presents a notch, and to the right of this, there is often another slight notch opposite the fundus of the gall-bladder.

The *posterior border* of the liver, which is directed backwards and upwards, is thick and rounded on the right side, but becomes gradually thinner towards the left. It is the most fixed part of the organ, and is firmly attached by areolar tissue to the diaphragm. This border of the liver is curved opposite to the projection of the vertebral column, and has a deep groove for the reception of the ascending vena cava.

Of the two *lateral borders* of the liver, the *right* is placed lower down, and is thick and obtuse; whilst the *left* is the thinnest part of the gland, is raised to a higher level, and reaches the cardiac part of the stomach.

Ligaments.—The ligaments of the liver, like its lobes and fissures, are commonly described as five, but it seems scarcely necessary to give distinct names to so many parts which are only folds of membrane. One of these, the *coronary ligament*, is the fold of peritoneum by which the posterior border of the liver is attached to the diaphragm: this border lies in contact with the diaphragm, in the greater part of its extent, between the upper and under layers of the peritoneal fold; but toward the two extremities of the organ these layers come into contact, and form two short mesenteries—the *right* and *left triangular ligaments*, of which the left is the longer and more distinct. Another of these so-called ligaments is the *broad, falciform*, or *suspensory ligament*, a wide thin membrane, composed of two layers of peritoneum, closely united together. By one of its margins it is connected with the under surface of the diaphragm, and with the posterior surface of the sheath of the right rectus muscle of the abdomen as low as the umbilicus; by another it is attached along the convex surface of the liver, from its posterior border to the notch in its anterior border: the remaining margin is free, and contains between its layers the *round ligament*, a dense fibrous cord, the remnant of the umbilical vein of the fœtus, which ascends from the umbilicus, within the lower edge of the broad ligament, and enters the longitudinal fissure on the under surface. These structures have been already referred to (p. 827).

Position with regard to neighbouring parts.—Occupying the right hypochondriac region, and extending across the epigastric region into a part of the left hypochondrium, the liver is accurately adapted to the vault of the diaphragm above, and is covered, to a small extent in front, by the abdominal parietes. The right portion reaches higher beneath the ribs than the left,

corresponding thus with the elevated position of the diaphragm on the right side. By means of the diaphragm, the liver is separated from the concave base of the right lung, the thin margin of which descends so as to intervene between the surface of the body and the solid mass of the liver—a fact well known to the auscultator.

The convex surface of the liver is protected, on the right, by the six or seven lower ribs, and in front by the cartilages of the same and by the ensiform cartilage—the diaphragm, of course, being interposed. Being suspended by ligaments to the diaphragm above, and supported below, in common with the rest of the viscera, by the abdominal muscles, the situation of the liver is modified by the position of the body, and also by the movements of respiration ; thus, in the upright or sitting posture, the liver reaches below the margin of the thorax ; but in the recumbent position, the gland ascends an inch or an inch and a half higher up, and is entirely covered by the ribs, except a small portion opposite the substernal notch. Again, during a deep inspiration, the liver descends below the ribs, and in expiration retires upwards behind them. In females the liver is often permanently forced downwards below the costal cartilages, owing to the use of tight stays ; sometimes it reaches nearly as low as the crest of the ilium ; and, in many such cases, its convex surface is indented from the pressure of the ribs.

To the left of the longitudinal fissure the liver is supported on the pyloric

Fig. 605.

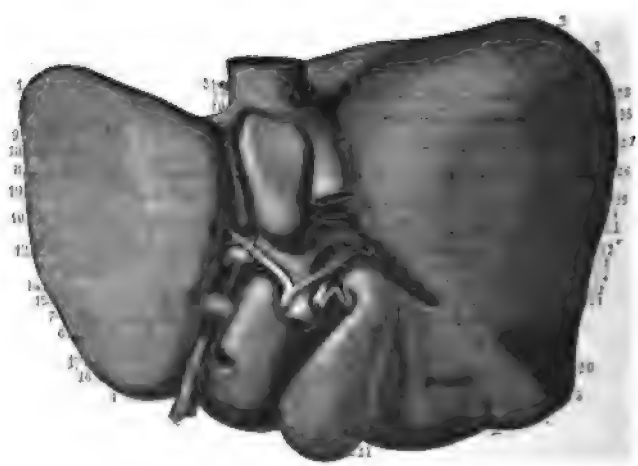


Fig. 605.—Lower Surface of the Liver with the Principal Bloodvessels and Ducts (from Sappey). ½

The liver has been turned over from left to right so as to expose the lower surface. 1, left lobe ; 2, 3, 4, 5, right lobe ; 6, lobulus quadratus ; 7, pons hepatis ; 8, 9, 10, lobulus Spigelii ; 11, lobulus caudatus ; 12, 13, transverse or portal fissure with the great vessels ; 14, hepatic artery ; 15, vena portæ ; 16, anterior part of the longitudinal fissure, containing 17, the round ligament or obliterated remains of the umbilical vein ; 18, posterior part of the same fissure, containing 19, the obliterated ductus venosus : 20, 21, 22, gall-bladder ; 23, cystic duct ; 24, hepatic duct ; 25, fossa containing 26, the vena cava inferior ; 27, opening of the capsular vein ; 28, small part of the trunk of the right hepatic vein ; 29, trunk of the left hepatic vein ; 30, 31, openings of the right and left diaphragmatic veins.

extremity and anterior surface of the stomach, on which it moves freely. When the stomach is quite empty, the left part of this surface of the liver may overlap the cardiac end of that viscus. To the right of the longitudinal fissure the liver rests and moves freely upon the first part of the duodenum, and upon the hepatic flexure of the colon, at the junction of the ascending and transverse portions of that intestine. Farther back it is in contact with the fore part of the right kidney and supra-renal capsule.

Vessels.—The two vessels by which the liver is supplied with blood are the hepatic artery and the vena portæ. The *hepatic artery* (p. 408), a branch of the cœliac axis, is intermediate in size between the other two branches of that trunk, being larger than the coronary artery of the stomach, but not so large as the splenic artery. Its size is, therefore, small in comparison with the organ to which it is distributed. It enters the transverse fissure, and there divides into a right and left branch, for the two principal lobes of the liver.

By far the greater part of the blood which passes through the liver,—and in this respect it differs from all other organs of the body,—is conveyed to it by a large vein, the *vena portæ* (p. 479). This vein is formed by the union of nearly all the veins of the chylopoietic viscera, viz., those from the stomach and intestines, the pancreas and spleen, the omentum and mesentery, and also those from the gall-bladder. It enters the *porta*, or transverse fissure, where, like the hepatic artery, it divides into two principal branches.

The hepatic artery and portal vein, lying in company with the bile duct, ascend to the liver between the layers of the gastro-hepatic omentum, above the foramen of Winslow, and thus reach the transverse fissure together. The relative position of the three structures is as follows :—The bile-duct is to the right, the hepatic artery to the left, and the large portal vein is behind the other two. They are accompanied by numerous lymphatic vessels and nerves. The branches of these three vessels accompany one another in their course through the liver nearly to their termination ; and in this course are surrounded for some distance by a common investment (Glisson's capsule), which is prolonged into the interior of the organ.

The *hepatic veins*, which convey the blood away from the liver, pursue through its substance an entirely different course from the other vessels, and pass out at its posterior border, where, at the bottom of the fossa already described, they end by two or three principal branches, besides other smaller ones, in the vena cava inferior.

The *lymphatics* of the liver, large and numerous, form a deep and a superficial set, already described (p. 493).

Nerves.—The *nerves* of the liver are derived partly from the cœliac plexus, and partly from the pneumogastric nerves, especially from the left pneumogastric. They enter the liver supported by the hepatic artery and its branches ; along with which they may be traced a considerable way in the portal canals, but their ultimate distribution is not known.

Excretory Apparatus.—The excretory apparatus of the liver consists of the hepatic duct, the cystic duct, the gall-bladder, and the common bile-duct.

The *hepatic* duct, formed by the union of a right and left branch, which issue from the bottom of the transverse fissure and unite at a very obtuse angle, descends to the right, within the gastro-hepatic omentum, in front of the vena portæ, and having the hepatic artery to its left side. Its diameter is about two lines, and its length nearly two inches. At its lower end it

meets with the cystic duct, descending from the gall-bladder; and the two ducts uniting together at an acute angle, form the common bile-duct.

The *gall-bladder* is a receptacle or reservoir for such bile as is not immediately required in digestion. It is a pear-shaped membranous sac, three or four inches long, about an inch and a half across at its widest part, and capable of containing from eight to twelve fluid-drachms. It is lodged obliquely in a fossa on the under surface of the right lobe of the liver, with its large end or *fundus*, which projects beyond the anterior border of the gland, directed downwards, forwards, and to the right, whilst its *neck* is inclined in the opposite direction.

The *upper surface* of the gall-bladder is attached to the liver by areolar tissue and vessels, along the fossa formed between the quadrate lobe and the remainder of the right lobe. Its *under surface* is free and covered by the peritoneum, which is here reflected from the liver, so as to include and support the gall-bladder. Sometimes, however, the peritoneum completely surrounds the gall-bladder, which is then suspended by a kind of mesentery at a little distance from the under surface of the liver. The *fundus* of the gall-bladder, which is free, projecting, and always covered with peritoneum, touches the abdominal parietes immediately beneath the margin of the thorax, opposite the tip of the tenth costal cartilage. Below, it rests on the commencement of the transverse colon; and, farther back, it is in contact with the duodenum, and sometimes with the pyloric extremity of the stomach. The *neck* of the gall-bladder, gradually narrowing, forms two curves upon itself like the letter S, and then, becoming much constricted, and changing its general direction altogether, it bends downwards and terminates in the cystic duct.

The gall-bladder is supplied with blood by the *cystic* branch of the right division of the hepatic artery, along which vessel it also receives nerves from the cœliac plexus. The cystic veins empty themselves into the vena portæ. Beale states that two large veins always accompany one artery.

The *cystic duct* is about an inch and a half in length. It runs downwards and to the left, thus forming an angle with the direction of the gall-bladder, and unites with the hepatic duct to form the common duct.

The *common bile duct, ductus communis choledochus*, the largest of the ducts, being from two to three lines in width, and nearly three inches in length, conveys the bile both from the liver and the gall-bladder into the duodenum. It continues downwards and backwards in the course of the hepatic duct, between the layers of the gastro-hepatic omentum, in front of the vena portæ, and to the right of the hepatic artery. Having reached the descending portion of the duodenum, it continues downwards on the inner and posterior aspect of that part of the intestine, covered by or included in the head of the pancreas, and, for a short distance, in contact with the right side of the pancreatic duct. Together with that duct, it then perforates the muscular wall of the intestine, and after running obliquely for three quarters of an inch between its several coats, and forming an elevation beneath the mucous membrane, it becomes somewhat constricted, and opens by a common orifice with the pancreatic duct on the inner surface of the duodenum, at the junction of the second and third portions of that intestine, and three or four inches below the pylorus.

Varieties.—The liver is not subject to great or frequent deviation from its ordinary form and relations. Sometimes it retains the thick rounded form which it presents in the fœtus; and it has occasionally been found without any division into lobes. On the contrary, Sœmmerring has recorded a case in which the adult liver was

divided into twelve lobes; and similar cases of subdivided liver (resembling that of some animals) have been now and then observed by others. A detached portion, forming a sort of *accessory* liver, is occasionally found appended to the left extremity of the gland by a fold of peritoneum containing blood-vessels.

The gall-bladder is occasionally wanting; in which case the hepatic duct is much dilated within the liver, or in some part of its course. Sometimes the gall-bladder is irregular in form, or is constricted across its middle, or, but much more rarely, it is partially divided in a longitudinal direction. Direct communications by means of small ducts (named hepato-cystic), passing from the liver to the gall-bladder, exist regularly in various animals; and they are sometimes found, as an unusual formation, in the human subject.

The right and left divisions of the hepatic duct sometimes continue separate for some distance within the gastro-hepatic omentum. Lastly, the common bile duct not unfrequently opens into the duodenum, apart from the pancreatic duct.

STRUCTURE OF THE LIVER.

Coats.—The liver has two coverings, viz. a serous or peritoneal investment, already sufficiently referred to, and a proper areolar coat.

The *areolar* or *fibrous* coat invests the whole gland. Opposite to the parts covered by the serous coat, it is thin and difficult to demonstrate; but where the peritoneal coat is absent, as at the posterior border of the liver, and in the portal fissure, it is denser and more evident. Its inner surface is attached to the hepatic glandular substance, being there continuous

Fig. 606.

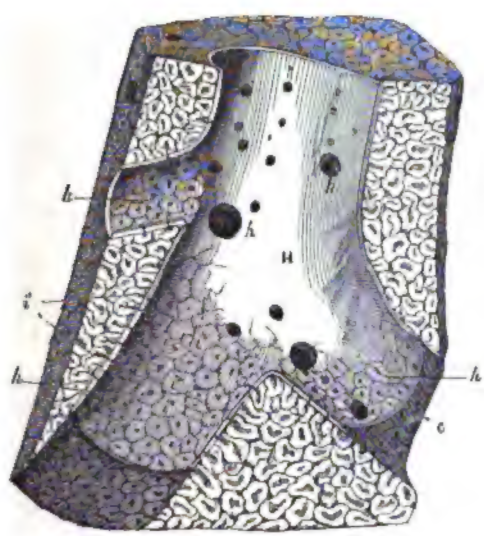


Fig. 606.—Section of a Portion of Liver passing Longitudinally through a considerable Hepatic Vein, from the Pig (after Kiernan).

H, hepatic venous trunk, against which the sides of the lobules (*l*) are applied; *h*, *h*, *h*, sublobular hepatic veins, on which the bases of the lobules rest, and through the coats of which they are seen as polygonal figures; *i*, mouth of the intralobular veins, opening into the sublobular veins; *i′*, intralobular veins shown passing up the centre of some divided lobules; *l*, *l*, cut surface of the liver; *c*, *c*, walls of the hepatic venous canal, formed by the polygonal bases of the lobules.

with the delicate areolar tissue which lies between the small lobules of the gland. At the transverse fissure it becomes continuous with the *capsule of Glisson*, by which name is designated a sheath of areolar tissue which surrounds the branches of the portal vein, hepatic artery, and hepatic duct, as they ramify in the substance of the liver, and which becomes more delicate as the vascular branches become smaller.

Lobules.—The proper substance of the liver, which has a reddish brown colour and a mottled aspect, is compact, but not very firm. It is easily cut or lacerated, and is not unfrequently ruptured during life from accidents in which other parts of the body have escaped injury. When the substance of the liver is torn, the broken surface is not smooth but coarsely granular, the liver being composed of a multitude of small *lobules*, which vary from half a line to a line in diameter.

These lobules are closely packed polyhedral masses, and in some animals, as in the pig, are completely isolated one from another by areolar tissue continuous with the fibrous coat of the liver and with the capsule of Glisson; but in the human subject, and in most animals, although they are very distinguishable on account of the disposition both of vessels and parenchyma, they are not distinctly separated, but exhibit continuity through their capillary networks and cellular constituents. Notwithstanding this, however, we may consider the lobules of the human liver as being marked out by slight interlobular intervals.

Fig. 607.

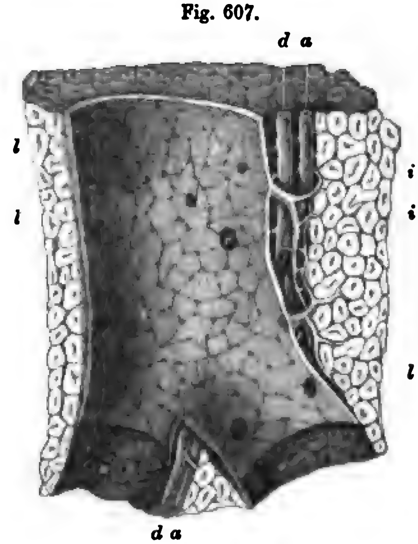


Fig. 607.—Longitudinal Section of a Portal Canal, containing a Portal Vein, Hepatic Artery, and Hepatic Duct, from the Pig (after Kiernan). $\frac{1}{1}$

P, branch of vena portæ, situated in *c*, *c*, a portal canal, formed amongst the lobules of the liver (*l*, *l*); *p*, *p*, vaginal branches of portal vein, giving off smaller ones (*i*, *i*), named interlobular veins; there are also seen within the large portal vein numerous orifices of the smallest interlobular veins arising directly from it; *a*, hepatic artery; *d*, hepatic duct.

The lobules of the liver have throughout its substance in general the polyhedral form of irregularly compressed spheroids; but on the surface they are flattened and angular. They are all compactly arranged round the sides of branches of the hepatic veins, each lobule resting by a smooth surface or *base*, upon the vein, and being connected with it by a small venous trunk, which arises in the centre of the lobule, and passes out from the middle of its base to end in the larger subjacent vessel. The small veins proceeding from the centre of the lobules are named the *intralobular* veins, and those on which the lobules rest, the *sublobular* veins. If one of these sublobular veins be opened, the bases of the lobules may be seen through

the coats of the vein, which are here very thin, giving a tesselated appearance, each little polygonal space representing the base of a lobule, and having in its centre a small spot, which is the mouth of the intralobular vein. When divided in the direction of a sublobular vein, the attached lobules present a foliated appearance, for that part of their surface which is not in contact with the vein is itself slightly lobulated. Cut in a transverse direction, the lobules present a polyhedral form.

The hepatic substance, as exhibited in the arrangement of each lobule, consists of masses of cells and a copious vascular network, closely interwoven, with the intervention of little other tissue. For the sake of convenience, the vascular structure of the liver may be considered first.

Blood-vessels.—The *hepatic veins* commence in the centre of each lobule by the union of its capillary vessels into a single independent intralobular

Fig. 608.

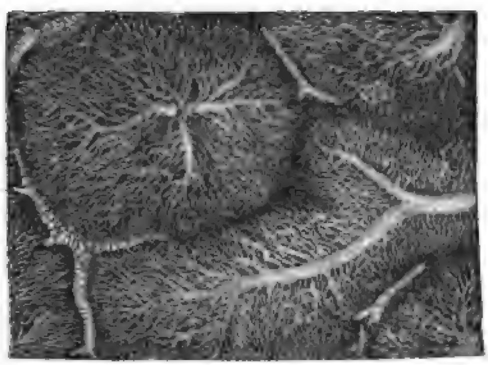


Fig. 608.—Capillary Network of the Lobules of the Rabbit's Liver (from Kölliker). $\frac{45}{1}$

The figure is taken from a very successful injection of the hepatic veins made by Harting: it shows nearly the whole of two lobules, and parts of three others: *p*, portal branches running in the interlobular spaces; *h*, hepatic veins penetrating and radiating from the centre of the lobules.

vein, as already stated. These minute intralobular veins open at once into the sides of the adjacent sublobular veins. The sublobular veins are of various sizes, and anastomose together. Uniting into larger and larger vessels, they end at length in hepatic venous trunks, which receive no intralobular veins. Lastly, these venous trunks, converging towards the posterior border of the liver, and receiving in their course other small sublobular veins, terminate in the vena cava inferior, as already described. In this course the hepatic veins and their successive ramifications are unaccompanied by any other vessel. Their coats are extremely thin; the sublobular branches adhere immediately to the lobules, and even the larger trunks have but a very slight areolar investment connecting them to the substance of the liver. Hence the divided ends of these veins are seen upon a section of the liver as simple open orifices, the thin wall of the vein being surrounded closely by the solid substance of the gland.

The vena portæ and hepatic artery, which, together with the biliary ducts,

enter the liver at the transverse fissure, have a totally different course, arrangement and distribution from those of the hepatic vein. Within the liver the branches of these three vessels lie together in certain canals, called

Fig. 609.

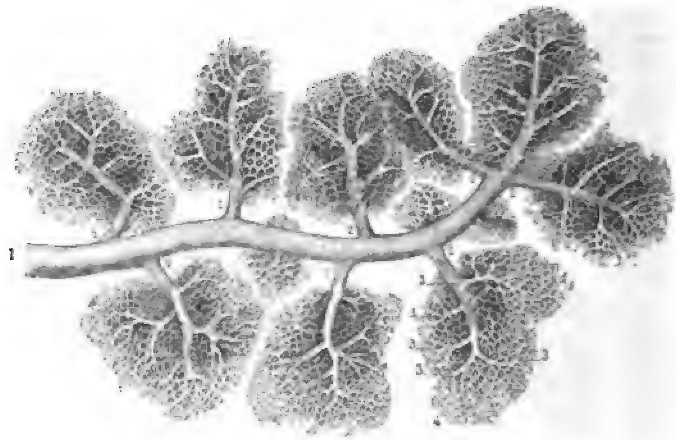


Fig. 609.—Injected Twig of a Hepatic Vein with Sublobular Veins Passing into the Hepatic Lobules (from Sappey). $\frac{20}{1}$

1, small sublobular hepatic vein ; 2, intralobular veins passing into the base of the lobules ; 3, their smaller subdivisions ; 4, capillary network of communication with the extreme ramifications of the vena portæ.

Fig. 610.

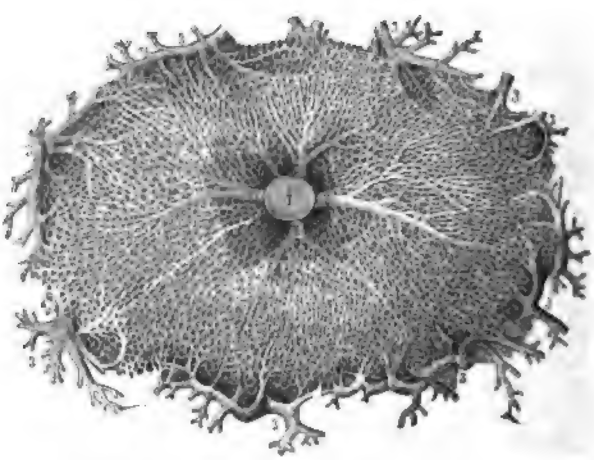


Fig. 610.—Cross Section of a Lobule of the Human Liver, in which the Capillary Network between the Portal and Hepatic Veins has been fully injected (from Sappey). $\frac{60}{1}$

1, section of the intralobular vein ; 2, its smaller branches collecting blood from the capillary network ; 3, interlobular branches of the vena portæ with their smaller ramifications passing inwards towards the capillary network in the substance of the lobule.

portal canals, which are tubular passages formed in the substance of the gland, commencing at the transverse fissure, and branching upwards and outwards from that part in all directions. Each portal canal (even the smallest) contains, as shown in a longitudinal section, one principal branch of the vena portæ, of the hepatic artery, and of the biliary duct; the whole being invested within the larger portal canals by the areolar tissue of the capsule of Glisson.

The *portal vein* subdivides into branches which ramify between the lobules, anastomosing freely around them, and are named *interlobular veins*. The twigs from these penetrate the lobules at their circumference, and end in the capillary network from which the intralobular (hepatic) veins take origin. Within the portal canals the branches of the portal veins receive small tributaries called "vaginal veins," which return to them the blood which has circulated in the capsule of Glisson, and also "venæ advehentes capsulares," from the fibrous coat of the liver.

The *hepatic artery* terminates in three sets of branches, termed vaginal, capsular, and interlobular. The *vaginal* branches ramify within the portal canals, supplying the walls of the ducts and Glisson's capsule. The *capsular* branches appear on the surface of the liver spread out on the fibrous sheath, and are accompanied by the veins which return their blood to the portal branches. The *interlobular* branches accompany the interlobular veins, but are of much smaller diameter. It has been supposed by Kiernan, Ferrein, and Theile, that the blood which they convey is entirely taken up by the portal veins before reaching the capillaries from which the hepatic veins take origin; but the view, which has been held by other anatomists, that the hepatic arteries transmit blood directly to the capillary network between the portal and hepatic veins, is supported by the experiments of Chrzonszczewsky, mentioned further on.

The *capillary network* is very close, and, in specimens in which it has been filled with transparent injection, can be seen to be continued uninterruptedly from one lobule to another.

The distribution of the portal and hepatic veins within the lobules, as just described, has suggested an explanation of the mottled aspect of the liver, an appearance which formerly led to the erroneous idea of there being two substances in each lobule, one darker than the other. The colour of the hepatic substance itself is pale yellow, and would be uniform throughout, were it not varied according to the quantity of blood contained in its different vessels. Thus, if the system of hepatic veins be congested, the centre of each lobule is dark, and its margin pale: this is the common case after death, and is named by Kiernan *passive* congestion. In what is considered an *active* state of hepatic congestion, the dark colour extends to the portal system, across the interlobular fissures, leaving intermediate spaces, which remain as irregular pale spots: this state occurs especially in diseases of the heart. When, on the other hand, the portal system is congested, which is rare, and occurs generally in children, the margins of the lobules are dark, and their centres pale.

The Hepatic Cells.—The principal part of the secreting substance of the liver, and that which seems to form nearly the whole bulk of the lobules when unprepared sections are examined with the microscope, consists of nucleated cells. The hepatic cells are of a spheroidal, compressed, or polyhedral form, having a mean diameter of from $\frac{1}{1000}$th to $\frac{1}{840}$th of an inch: according to Henle some of them are only $\frac{1}{1710}$th of an inch in diameter. They present some colour even when highly magnified, being of a faint yellowish hue. They usually include a very clear bright vesicular nucleus of a rounded form, within which again one or two nucleoli may be

smaller and flatter, by the line of attachment of the fold of peritoneum named the falciform ligament.

The *under surface*, looking downwards and backwards, is concave and uneven, invested with peritoneum everywhere except where the gall bladder is adherent to it, and at the portal fissure and fissure of the ductus venosus, which give attachment to the small omentum, the fold of peritoneum which passes round the blood-vessels and ducts of the viscus. On this surface the lobes and fissures of the liver are observed.

The lobes of the liver, five in number, are named the right and the left, the lobe of Spigelius, the caudate or tailed lobe, and the square lobe.

The *right* and *left* lobes are separated from each other on the under surface by the longitudinal fissure, and in front by the interlobular notch: on the convex surface of the liver there is no other indication of a separation between them than the line of attachment of the broad ligament. The right lobe is much larger and thicker than the left, which constitutes only about one-fifth or one-sixth of the entire gland.

The other three lobes are small, and might be said to form parts of the right lobe, on the under surface of which they are situated.

The *lobulus quadratus* is that part which is situated between the gall-bladder and the great longitudinal fissure, and in front of the fissure for the portal vein. Its greatest diameter is from before backwards.

The *lobulus Spigelii*, more prominent and less regular in shape than the quadrate lobe, lies behind the fissure for the portal vein, and is bounded on the right and left by the fissures which contain the inferior vena cava and the remains of the ductus venosus.

The *lobulus caudatus* is a sort of ridge which extends from the base of the Spigelian lobe to the under surface of the right lobe. This, in the natural position of the parts, passes forwards above the foramen of Winslow, the Spigelian lobe itself being situated behind the small omentum, and projecting into the omental sac.

The fissures.—These are likewise five in number, and are seen on the under surface only. They have all been already incidentally referred to.

The *transverse* fissure, or *portal* fissure, is the most important, because it is here that the great vessels and nerves enter, and the hepatic duct passes out. It lies transversely between the lobulus quadratus and lobulus Spigelii, and meets the longitudinal fissure nearly at right angles. At the two extremities of this fissure, the right and left divisions of the hepatic artery and portal vein, together with the nerves and deep lymphatics enter the organ, while the right and left hepatic ducts emerge.

The *longitudinal* fissure, which separates the right and the left lobes of the liver from each other, is divided into two parts by its meeting with the transverse fissure. The anterior part, named the *umbilical* fissure, contains the umbilical vein in the fœtus, and the remnant of that vein in the adult, which then constitutes the round ligament. It is situated between the square lobe and the left lobe of the liver, the substance of which often forms a bridge across the fissure, so as to convert it partially or completely into a canal. The posterior part is named the *fissure* of the *ductus venosus* (fossa ductus venosi); it continues the umbilical fissure backwards between the lobe of Spigelius and the left lobe; and it lodges the ductus venosus in the fœtus, and in the adult a slender cord or ligament into which that vein is converted.

The *fissure* or *fossa* of the *vena cava* is situated at the back part of the liver, between the Spigelian lobe on the left and the right lobe, and is

separated from the transverse fissure by the caudate lobe. It is prolonged upwards in an oblique direction to the posterior border of the liver, and may be said to join behind the Spigelian lobe with the fissure for the ductus venosus. It is at the bottom of this fossa that the blood leaves the liver by the hepatic veins, which end here in the vena cava. The substance of the liver in some cases unites around the vena cava, and encloses that vessel in a canal.

The last remaining fissure, or rather *fossa* (fossa cystis felleæ), is that for the lodgment of the gall-bladder; it is sometimes continued into a slight notch on the anterior margin of the liver.

Two shallow impressions are seen on the under surface of the right lobe; one in front (*impressio colica*), corresponding with the hepatic flexure of the colon; and one behind (*impressio renalis*), corresponding with the right kidney.

The *anterior border* of the liver, a thin, free, and sharp margin, is the most movable part of the gland. Opposite the longitudinal fissure the anterior border presents a notch, and to the right of this, there is often another slight notch opposite the fundus of the gall-bladder.

The *posterior border* of the liver, which is directed backwards and upwards, is thick and rounded on the right side, but becomes gradually thinner towards the left. It is the most fixed part of the organ, and is firmly attached by areolar tissue to the diaphragm. This border of the liver is curved opposite to the projection of the vertebral column, and has a deep groove for the reception of the ascending vena cava.

Of the two *lateral borders* of the liver, the *right* is placed lower down, and is thick and obtuse; whilst the *left* is the thinnest part of the gland, is raised to a higher level, and reaches the cardiac part of the stomach.

Ligaments.—The ligaments of the liver, like its lobes and fissures, are commonly described as five, but it seems scarcely necessary to give distinct names to so many parts which are only folds of membrane. One of these, the *coronary ligament*, is the fold of peritoneum by which the posterior border of the liver is attached to the diaphragm: this border lies in contact with the diaphragm, in the greater part of its extent, between the upper and under layers of the peritoneal fold; but toward the two extremities of the organ these layers come into contact, and form two short mesenteries—the *right* and *left triangular ligaments*, of which the left is the longer and more distinct. Another of these so-called ligaments is the *broad*, *falciform*, or *suspensory ligament*, a wide thin membrane, composed of two layers of peritoneum, closely united together. By one of its margins it is connected with the under surface of the diaphragm, and with the posterior surface of the sheath of the right rectus muscle of the abdomen as low as the umbilicus; by another it is attached along the convex surface of the liver, from its posterior border to the notch in its anterior border: the remaining margin is free, and contains between its layers the *round ligament*, a dense fibrous cord, the remnant of the umbilical vein of the fœtus, which ascends from the umbilicus, within the lower edge of the broad ligament, and enters the longitudinal fissure on the under surface. These structures have been already referred to (p. 827).

Position with regard to neighbouring parts.—Occupying the right hypochondriac region, and extending across the epigastric region into a part of the left hypochondrium, the liver is accurately adapted to the vault of the diaphragm above, and is covered, to a small extent in front, by the abdominal parietes. The right portion reaches higher beneath the ribs than the left,

that, the cells being placed closely together, the bile either passes by irregular interstices between them, or from one cell to another, to reach the smallest ducts at the circumference of the lobules.

Beale, who has investigated the subject with great care, believes that he has succeeded in demonstrating the existence of a basement membrane inclosing, in a plexus of tubes, the intralobular rows or columns of hepatic cells. This basement membrane, he conceives, lines the interstices between the capillary blood-vessels forming the intralobular plexus; and he states that, although in the adult it becomes so closely incorporated with the walls of the blood-vessels that it is scarcely to be demonstrated as a distinct structure, yet in the fœtus, the walls of these tubes and those of the vessels are quite distinct. The minute ducts are considered by Beale to be directly continuous with this tubular network: but the tubules containing the hepatic cells, being $\frac{1}{1000}$th of an inch in diameter, and the smallest ducts $\frac{1}{3000}$th or less, there is a great difference in their size; this difference he holds, however, is only similar to that which is found, in some other glandular organs, between the proper secreting cavity and the ductal passages.

Kölliker has become convinced of the correctness of Beale's account from an examination of his preparations. Henle believes that the interlobular bile ducts are completely shut off from the cellular substance of the lobules, which was the theory proposed by Handfield Jones; and he suggests that the hepatic cells are entirely engaged in the amyloid function of the liver, and unconnected with the biliary secretion.

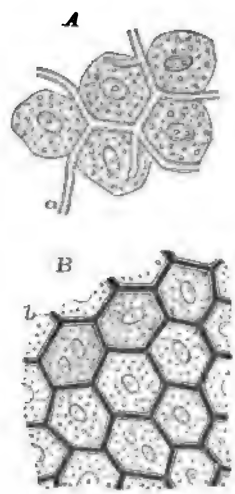
According to such views as those before stated, the anastomosing network of ducts described by Kiernan would be regarded as artificial passages between the cells, formed by the force of injection; and there is no doubt that passages of that sort may be made. In recent years, however, Budge, Andrejewic, Hyrtl, Frey, and other observers have succeeded in displaying by injection of the cellular substance of the lobules a network of fine canals of cylindrical form and regular diameter, and having therefore a character which cannot be explained on the supposition that they are irregular interspaces of accidental origin. The apparent improbability of the ducts of a secreting gland taking origin in minute tubes destitute of epithelium, and external to secreting cells, has led to great opposition to the view that the ducts in question are really bile ducts; and Reichert has suggested that they are lymphatics: but within the present year, a set of researches have been published which invest the theory that the bile ducts begin within a fine intralobular plexus, with additional weight. Chrzonszczewsky, pursuing a method of experimenting by what may be called the natural injection of colouring matter into the vessels of living animals, by which he had previously succeeded in colouring the tubes and vessels of the kidney, sought for a colouring matter which, when introduced into the blood, would be eliminated in part by the bile without dyeing the textures indiscriminately; and, after numerous failures, he at last found one substance with the requisite properties,—viz., the sulpho-indigotate of soda (in use under the name of "indigo-carmine"). A saturated watery solution of this substance was introduced, in repeated doses, into the circulation of dogs and sucking-pigs, by the jugular vein; and in an hour and a half afterwards, while the animals were still living, the blood-vessels were either washed out with chloride of potassium introduced by the portal vein, or they were injected with gelatine and carmine. In specimens prepared in this way, Chrzonszczewsky obtained an extremely fine network of gall ducts

throughout each lobule, injected blue, while the intervening cells remain free from colour. These canals he describes as of regular diameter, without increase of size where they anastomose, and by teasing he obtains portions of them with distinct walls standing out free from the cells: by warming the section to 113° Fah., the blue colour is destroyed while the canals still remain visible. By killing the animals sooner after the injection, the blue colouring matter was found within the hepatic cells, thus demonstrating that it was through their agency that the canals were filled. Further experiments were made in animals in which the portal vein and hepatic artery had been tied, and the result obtained was that when the hepatic artery

Fig. 615.—Two small Fragments of Hepatic Lobules, of which the smallest Intercellular Biliary Ducts were filled with Colouring Matter during Life, highly magnified (from Chrzonszczewsky).

In A, the hepatic cells have been separated, and the intercellular ducts, *a*, are seen not only passing between them, but also in part projecting free; in this preparation the colour was discharged by heat: in B, the colouring matter remains in the ducts, and the cells are more closely connected together.

Fig. 615.



had been tied, the peripheral parts of the lobules showed the blue canals, while the centre of each was left colourless; and that when the portal vein had been tied, the reverse effect was produced; the centre of each lobule showing blue canals, while in the intervening spaces only larger ducts were seen. It is worthy of remark that the appearance of fibres crossing the capillary spaces observed by Henle in sections washed with alkali, might very well be due to such canals as those described by Budge, Chrzonszczewsky, and others.

Structure of the ducts.—The bile-ducts have strong distensible areolar coats, containing abundant elastic tissue, and their mucous membrane is lined with columnar epithelium. The minute ramifications between the lobules have walls of a more homogeneous nucleated tissue, but the lining of columnar epithelium is still found in them (Henle). The mucous membrane of those which are less minute presents numerous openings, which are scattered irregularly in the larger ducts, but in the subdivisions are arranged in two longitudinal rows, one at each side of the vessel. These openings were formerly supposed to be the orifices of mucous glands; but while the main ducts are studded with true mucous glands of lobulated form and with minute orifices, the larger openings now referred to belong, as was pointed out by Theile, to sacs and ramified tubes which occasionally anastomose, and may be studded all over with cæcal projections. Sappey and Henle, who have made these processes the subject of special investigation, find that they are so numerous as sometimes to conceal the parent tube, and on this Henle bases his suggestion (System. Anat.) that they are engaged in the secretion of the bile.

Aberrant biliary ducts.—In the duplicature of the peritoneum forming the left lateral ligament of the liver, and also in the two fibrous bands which sometimes convert the fossa for the vena cava and the fissure of the umbilical vein into canals, there have been found biliary ducts of considerable

size which are not surrounded with lobules. These aberrant ducts, as they might be called, were described by Ferrein and by Kiernan; they anastomose together in form of a network, and are accompanied by branches of the vena portæ, hepatic artery, and hepatic vein.

Structure of the gall-bladder.—Besides the peritoneal investment, the walls of the gall-bladder are formed of two distinct layers of tissue constituting its areolar or fibrous and its mucous coats.

The *areolar* coat is strong, and consists of bands of dense shining white fibres, which interlace in all directions. These fibres resemble those of areolar tissue. In quadrupeds recently-killed the gall-bladder contracts on the application of a stimulus; and in the larger species, as well as in man, muscular fibres of the plain variety have been found mingled with those of the areolar coat. These fibres have principally a longitudinal direction, but some run transversely. Their nuclei are indistinct. The areolar coat forms the framework of the organ, and supports the larger blood-vessels and lymphatics.

The *mucous* coat, which is generally strongly tinged of a yellowish-brown colour with bile, is elevated upon its inner surface into very numerous small ridges, which, uniting together into meshes, leave between them depressions of different sizes and of various polygonal forms. This structure gives to the interior of the gall-bladder an areolar aspect, which is similar to what is seen on a smaller scale in the vesiculæ seminales. These areolar intervals become smaller towards the fundus and neck of the gall-bladder; and at the bottom of the larger ones, other minute depressions, which may be seen with a magnifying lens, apparently lead into numerous mucous recesses or follicles. The whole of the mucous membrane is covered by columnar epithelium, and it secretes an abundance of viscid mucus.

At the places where the neck of the gall-bladder curves on itself, there are strong folds or projections of its mucous and areolar coats into the interior.

In the *cystic duct*, the mucous membrane is elevated internally in a singular manner into a series of crescentic folds, which are arranged in an oblique direction, and succeed closely to each other, so as to present very much the appearance of a continuous spiral valve. When distended, the outer surface of the duct appears to be indented in the situation of these folds, and dilated or swollen in the intervals, so as to present an irregularly sacculated or twisted appearance. It is of importance to note the influence of this valve in causing the retention of biliary concretions in the gall-bladder.

Among the monographs which give an account of the structure of the liver, the following may be specially mentioned :—Kiernan, in Phil. Transactions, 1833; Theile, in Wagner's Handwörterbuch d. Physiologie, p. 308; Rainey on the Capillaries of the Liver, in Microsc. Journal, I. p. 231; Handfield Jones, in Phil. Transactions, 1849 and 1853; Budge, in Müller's Archiv, 1850; Beale, Lectures in Medical Times and Gazette, 1856, and "On some points in the Anatomy of the Liver," in Philos. Trans. 1856; Chrzonszczewsky, in Virchow's Archiv, XXXV. p. 153, 1866.; Frey, in Zeitsch. f. Wissensch. Zoologie, March, 1866.

THE BILE.

The bile, as it flows from the liver, is a thin greenish yellow fluid; but that which remains in the gall-bladder becomes darker, more viscid, and ropy. It contains as adventitious particles mucus and epithelium corpuscles, but no hepatic cells. The

specific gravity of the bile is from 1·026 to 1·030. It has a sweetish bitter taste, and an alkaline reaction. It is a saponaceous compound, containing the following ingredients:—water, mucus, colouring matters (composed, according to Berzelius, of a yellow substance named cholepyrrhine, a brown substance named bilifulvine, and a green matter or biliverdine), fatty acids, viz., the margaric and oleic, combined with soda, free fat, cholesterine, salts, and, lastly, the most important ingredient of the bile, namely, the proper biliary matter, which consists, according to Strecker and Lehmann, of two "conjugated acids," formed by the union of one acid, the Choleic, in two isomeric forms (the cholic and choloidic acids of some authors) with Glycin and Taurin respectively. Thus the Glyco-cholic and Tauro-cholic acids are formed, each of them consisting principally of carbon and hydrogen, but both containing nitrogen, and the latter a considerable quantity of sulphur. They are combined with soda, but are very readily decomposed, giving rise to ammoniacal and other compounds. Of these two acids the glyco-cholic is the most important. The bile-pigment affords the most characteristic tests for the detection of biliary matter.

DEVELOPMENT AND FŒTAL PECULIARITIES OF THE LIVER.

The liver begins to be formed at a very early period of fœtal life. Both in the mammal, as seen by Bischoff, and in the bird, as Remak's researches show, it begins in the form of two blind processes from the intestinal tube, immediately beneath the dilatation for the stomach. According to Remak, these processes involve both the epithelial and fibrous layers of the intestine; and the fibrous layer rapidly growing, involves the omphalo-mesenteric vein and forms the outline of the liver: meanwhile the internal structure takes origin by the growth of anastomosing cylinders of cells from the epithelial layer, and of tufts of blood-vessels.

Fig. 616.

Fig. 616.—Early Condition of the Liver in the Chick on the Third Day of Incubation (from J. Müller). $\frac{10}{1}$

1, the heart, as a simple curved tube; 2, 2, the intestinal tube; 3, conical protrusion of the coat of the commencing intestine, on which the blastema of the liver (4) is formed; 5, portion of the layers of the germinal membrane, passing into the yolk-sac.

The gall-bladder, according to some authors, is developed as a branch or diverticulum from the bile duct outside the liver; but Meckel describes it as arising in a deep notch in the substance of the gland. It is at first tubular, and then has a rounded form. The alveoli in its interior appear about the sixth month. At the seventh month it first contains bile. In the fœtus its direction is more horizontal than in the adult.

Size.—In the human fœtus, at the third or fourth week, the liver is said to constitute one-half of the weight of the whole body. This proportion gradually decreases as development advances, until at the full period the relative weight of the fœtal liver to that of the body is as 1 to 18.

In early fœtal life, the right and left lobes of the liver are of equal, or nearly equal, size. Later, the right preponderates, but not to such an extent as after birth. Immediately before birth the relative weight of the left lobe to the right is nearly as 1 to 1·6.

Position.—In consequence of the nearly equal size of the two lobes, the position of the fœtal liver in the abdomen is more symmetrical than in the adult. In the very young fœtus it occupies nearly the whole of the abdominal cavity; and at

the full period it still descends an inch and a half below the margin of the thorax, overlaps the spleen on the left side, and reaches nearly down to the crest of the ilium on the right.

Form, Colour, &c.—The fœtal liver is considerably thicker from above downwards than that of the adult. It is generally of a darker hue. Its consistence and specific gravity are both less than in the adult.

Blood-Vessels.—The blood-vessels of the fœtal liver present several important peculiarities, with which, indeed, those previously mentioned are more or less connected. Up to the moment of birth, the greater part of the blood returned from the placenta by the umbilical vein passes through the liver of the fœtus before it reaches the heart; while a smaller part is transmitted more directly to the right auricle. During fœtal life, the umbilical vein runs from the umbilicus along the free margin of the suspensory ligament towards the anterior border and under surface of the liver, beneath which it is lodged in the umbilical fissure, and proceeds as far as the transverse fissure. Here it divides into *two* branches; one of these, the smaller of the two, continues onward in the same direction, and joins the vena cava; this is the *ductus venosus*, which occupies the posterior part of the longitudinal fissure, and gives to it the name of the fossa of the ductus venosus. The other and larger branch (the trunk of the umbilical vein) turns to the right along the transverse or portal fissure, and ends in the vena portæ, which, in as much as it proceeds from the veins of the digestive organs, is in the fœtus comparatively of small dimensions. Moreover, the umbilical vein, as it lies in the umbilical fissure, and before it joins the vena portæ, gives off some lateral branches, which enter the left lobe of the liver. It also sends a few branches to the square lobe and to the lobe of Spigelius.

Fig. 617.

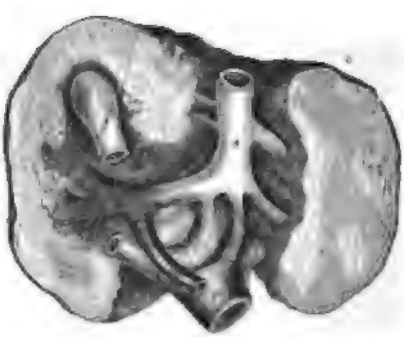


Fig. 617.—Under Surface of the Fœtal Liver, with its great Blood-vessels, at the full Period. ½

The rounded outline of the organ, and the comparatively small difference of size between its two lobes, are seen: *a*, the umbilical vein, lying in the umbilical fissure, and turning to the right side at the transverse fissure (*o*), to join the vena portæ (*p*): the branch marked *d*, named the ductus venosus, continues straight on to join the vena cava inferior (*c*): a few branches of the umbilical vein enter the substance of the liver at once; *g*, the gall-bladder.

The blood of the umbilical vein may therefore be considered as reaching the ascending vena cava in three portions. Some is carried into it by the more direct passage of the ductus venosus; another, the principal portion, passes first through the portal veins, and then through the hepatic veins; whilst a third portion, supplied by direct branches to the liver, is also returned to the cava by the hepatic veins.

Changes after birth.—Immediately after birth, at the cessation of the current which previously passed through the umbilical vein, and on the establishment of an increased circulation through the lungs, the supply of blood to the liver is diminished by nearly two-thirds. The umbilical vein and ductus venosus become empty and contracted, and soon afterwards they begin to be obliterated, and are ultimately converted into the fibrous cords already described,—that one which represents the umbilical vein constituting the round ligament of the liver. At the end of six days the ductus venosus has been found to be closed; but it sometimes continues open for several weeks. That portion of the umbilical vein which supplied direct branches to the liver remains open, though diminished in size, and, being in communication with the left branch of the vena portæ, continues afterwards to transmit blood to a part of the liver from that vessel.

Concurrently with, and doubtless in some measure dependent on, the sudden

diminution in the quantity of blood supplied to the liver after birth, this organ appears at first to become absolutely lighter; and, according to some data, this decrease of weight is not recovered from until the conclusion of the first year. After that period, the liver, though it increases in size, grows more slowly than the body, so that its relative weight in proportion to the body, which was 1 to 18 just before birth, becomes gradually less and less. At about five or six years of age it has reached the proportion maintained during the rest of life, viz. 1 to 36.

The relative weight of the left lobe to that of the right (which, as above stated, is about 1 to 1.6 immediately before birth) undergoes a subsequent diminution. Thus, at a month old, it has been found to be as 1 to 3, and in after-life the proportion is generally 1 to 4 or 5.

THE PANCREAS.

The *pancreas* is a long, narrow, flattened gland, larger at one end than at the other, and lying deeply in the cavity of the abdomen, immediately behind the stomach, and opposite the first lumbar vertebra. Its larger end, the *head*, turned to the right, is embraced by the curvature of the duodenum, whilst its left or narrow extremity, the *tail*, reaches to a somewhat higher level, and is in contact with the spleen. It extends across the epigastric into both hypochondriac regions.

The right or large end of the pancreas is bent from above downwards, and accurately fills the curvature of the duodenum, to which it is closely adherent. The lower extremity of this curved portion passes to the left, behind

Fig. 618.

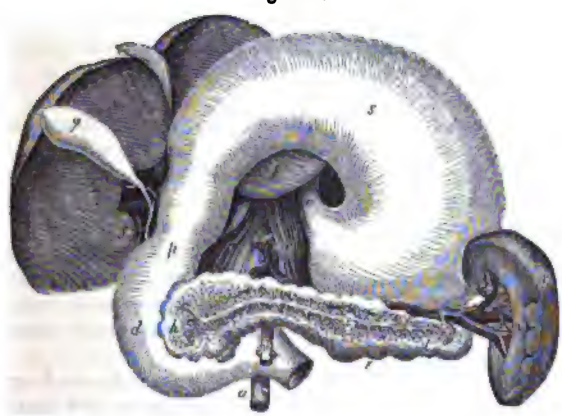


Fig. 618.—View of the Pancreas and surrounding Organs. ½

In this figure, which is altered from Tiedemann, the liver and stomach are turned upwards to show the duodenum, the pancreas, and the spleen : *l*, the under surface of the liver ; *g*, gall-bladder ; *f*, the common bile duct, formed by the union of the cystic duct, from the gall-bladder, and the hepatic duct coming from the liver ; *o*, the cardiac end of the stomach, where the œsophagus enters ; *s*, under surface of the stomach ; *p*, pyloric end of the stomach ; *d*, duodenum ; *h*, head of the pancreas ; *t*, tail, and *i*, body of that gland ; the substance of the pancreas is removed in front, to show the pancreatic duct (*e*) and its branches ; *r*, the spleen ; *v*, the hilus, at which the blood-vessels enter ; *c*, *c*, crura of the diaphragm ; *n*, superior mesenteric artery ; *a*, aorta.

the superior mesenteric vessels, forming the posterior wall of a sort of canal in which they are enclosed. This part of the gland is sometimes marked off from the rest, and is then named the *lesser pancreas*.

The pancreas varies considerably, in different cases, in its size and weight. It is usually from 6 to 8 inches long, about 1½ inch in average breadth, and from half an

inch to an inch in thickness, being thicker at its head and along its upper border than elsewhere. The weight of the gland, according to Krause and Clendenning, is usually from 2½oz. to 3½oz.; but Meckel has noted it as high as 6 oz., and Sœmmerring as low as 1½ oz.

The anterior surface of the pancreas is covered with the posterior wall of the sac of the omentum, and is concealed by the stomach, which glides upon it. The posterior surface is attached by areolar tissue to the vena cava, the aorta, the superior mesenteric artery and vein, the commencement of the vena portæ, and the pillars of the diaphragm, all of which parts, besides many lymphatic vessels and glands, are interposed between it and the upper lumbar vertebræ: to the left of the vertebral column it is attached similarly to the left supra-renal capsule and kidney and to the renal vessels. Of the large vessels situated behind the pancreas, the superior mesenteric artery and vein are embraced by the substance of the gland, so as sometimes to be enclosed in a complete canal, through which they pass downwards and forwards, and then emerge from beneath the lower border of the pancreas, between it and the termination of the duodenum. The cœliac axis is above the pancreas; and in a groove along the upper border of the gland are placed the splenic artery and vein, the vein pursuing a straight, and the artery a tortuous course, and both supplying numerous branches to the pancreas, the narrow extremity of which is thus attached to the inner surface of the spleen. The head of the pancreas, embraced by the inner curved border of the duodenum, is attached more particularly to the descending and transverse portions of that intestine, beyond which it projects somewhat both in front and behind. The ductus communis choledochus passes down behind the head of the pancreas, and is generally received into a groove or canal in its substance.

Structure.—The pancreas belongs to the class of conglomerate glands. In its general characters, and also in its intimate structure, which is racemose, it closely resembles the salivary glands, but it is somewhat looser and softer in its texture. It consists of numerous lobes and lobules, of various sizes, held together by areolar tissue, blood-vessels, and ducts. The lobules, aggregated into masses, are rounded or slightly flattened at the sides, so as to be moulded or adjusted compactly to each other; their substance is of a reddish cream-colour, and the arrangement of the commencing ducts and vessels is similar to that in the lobules of the parotid gland, which has been already described (p. 816).

The principal excretory duct, called the *pancreatic duct* or *canal of Wirsung* (by whom it was discovered in the human subject in 1642), runs through the entire length of the gland, from left to right, buried completely in its substance, and placed rather nearer its lower than its upper border. Commencing by the union of the small ducts derived from the groups of lobules composing the tail of the pancreas, and receiving in succession at various angles, and from all sides, the ducts from the body of the gland, the canal of Wirsung increases in size as it advances towards the head of the pancreas, where, amongst other large branches, it is usually joined by one derived from that portion of the gland called the lesser pancreas. Curving slightly downwards, the pancreatic duct then comes into contact with the left side of the ductus communis choledochus, which it accompanies to the back part of the descending portion of the duodenum. Here the two ducts, placed side by side, pass very obliquely through the muscular and areolar coats of the intestine, and terminate, as already described (p. 868), on its internal mucous surface, by a common orifice, situated at

the junction of the descending and horizontal portions of the duodenum, between three and four inches below the pylorus. The pancreatic duct, with its branches, is readily distinguished from the glandular substance, by the very white appearance of its thin fibrous walls. Its widest part, near the duodenum, is from 1 line to 1½ line in diameter, or nearly the size of an ordinary quill; but it may be easily distended beyond that size. It is lined by a remarkably thin and smooth mucous membrane, which near the termination of the duct occasionally presents a few scattered follicles.

Varieties.—Sometimes the pancreatic duct is double up to its point of entrance into the duodenum; and a still farther deviation from the ordinary condition is not unfrequently observed, in which there is a *supplementary* duct, derived from the lesser pancreas or some part of the head of the gland, opening into the duodenum by a distinct orifice, at a distance of even one inch or more from the termination of the principal duct. It sometimes occurs that the pancreatic duct and the common bile duct open separately into the duodenum.

Vessels and Nerves.—Like the salivary glands, the pancreas receives its blood-vessels at numerous points. Its arteries are derived from the splenic and from the superior and inferior pancreatico-duodenal branches of the hepatic and superior mesenteric. Its blood is returned by the splenic and superior mesenteric veins. Its lymphatics terminate in the lumbar vessels and glands. The nerves of the pancreas are derived from the solar plexus.

Development.—In its origin and development, the pancreas altogether resembles the salivary glands. It appears a little earlier than these glands, in the form of a small bud from the left side of the intestinal tube, close to the commencing spleen.

Secretion.—Like the saliva, the pancreatic juice is a clear colourless fluid, which has diffused in it a few microscopic corpuscles; it has an alkaline reaction, and coagulates in white flakes when heated. The coagulum is caused by the presence of an albuminoid substance—*pancreatin*—which, like salivin, has the property of converting starch into sugar. The pancreatic juice contains likewise chlorides of sodium and potassium, and phosphates of lime, soda, and magnesia. It readily undergoes decomposition on exposure.

THE SPLEEN.

The spleen is a soft, highly vascular, and easily distensible organ, of a dark bluish or purplish grey colour. It is situated in the left hypochondrium, at the cardiac end of the stomach, between that viscus and the diaphragm, and is protected by the cartilages of the ribs. It is the largest of the structures termed ductless glands, and it is now generally admitted to be intimately connected with the process of sanguification, and is most probably the seat of the formation of blood corpuscles.

The shape of the spleen is irregular and somewhat variable: it forms a compressed oval mass, placed nearly vertically in the body, and having two faces, one external, convex, and free, which is turned to the left, the other internal and concave, which is directed to the right, and is applied to the cardiac end or great cul-de-sac of the stomach: it also presents an anterior sharper and a posterior blunter margin.

The convex face of the spleen, smooth and covered by the peritoneum, is in contact with the under surface of the left side of the diaphragm, and corresponds with the ninth, tenth, and eleventh ribs. The internal concave face is divided by a vertical fissure, named the *hilus*, into an anterior and posterior portion, both covered with peritoneum, continued round the borders from the convex surface. The anterior of these two portions is the larger, and is closely applied to the stomach; the posterior is in apposition with the left pillar of the diaphragm and left suprarenal capsule. The anterior border of the spleen is thinner than the posterior, and is often

slightly notched, especially towards the lower part. The lower end is pointed, and is in contact with the left end of the arch of the colon, or with the transverse meso-colon. The position of the hilus corresponds with the line of attachment of the gastro-splenic omentum. Along the bottom of this fissure are large openings or depressions, which transmit blood-vessels, with lymphatics and nerves, to and from the interior of the organ. In some cases there is no distinct fissure, but merely a row of openings for the vessels; and in others the situation of the hilus is occupied by a longitudinal ridge, interrupted by the vascular orifices. The peritoneal connections of the spleen have been already described (pp. 827 and 830). A portion of variable extent behind the hilus, and towards its lower end, will usually be observed deriving its peritoneal covering from the sac of the omentum.

The spleen varies in magnitude more than any other organ in the body; and this not only in different subjects, but in the same individual, under different conditions, sometimes appearing shrunk, and at others being much distended. On this account it is difficult or impossible to state what are its ordinary weight and dimensions: in the adult it measures generally about 5 or 5½ inches from the upper to the lower end, 3 or 4 inches from the anterior to the posterior border, and 1 or 1½ inch from its external to its internal surface; and its usual volume, according to Krause, is from 9¾ to 15 cubic inches. In the greater number of a series of cases examined by Reid, its weight ranged from 5 to 7 oz. in the male, and was somewhat less in the female; but even when perfectly free from disease, it may fluctuate between 4 and 10 ounces. Gray states that the proportion of the spleen to the weight of the adult body varies from 1 : 320 to 1 : 400. In the fœtus the proportion is as 1 : 350. After the age of forty the average weight gradually diminishes, so that in old age the weight of the spleen is to that of the body as 1 : 700 (H. Gray). The specific gravity of this organ, according to Haller, Sœmmerring, and Krause, is about 1·060. In intermittent and some other fevers the spleen is much distended and enlarged, reaching below the ribs, and often weighing as much as 18 or 20 lbs. In enlargement and solidification it has been known to weigh upwards of 40 lbs.; and it has been found reduced by atrophy to the weight of two drachms.

Small detached roundish nodules are occasionally found in the neighbourhood of the spleen, similar to it in substance. These are commonly named *accessory* or *supplementary* spleens (splenculi; lienculi). Of these one or two most commonly occur, but a greater number, and even up to twenty-three, have been met with. They are small rounded masses, varying from the size of a pea to that of a walnut. They are usually situated near the lower end of the spleen, either in the gastro-splenic omentum, or in the great omentum. These separate splenculi in the human subject bring to mind the multiple condition of the spleen in some animals, and also the deeper notching of the anterior margin of the organ which sometimes occurs in man.

Structure.—The spleen has two membranous investments—a serous coat derived from the peritoneum, and a special albugineous fibro-elastic tunic. The substance of the organ, which is very soft and easily lacerated, is of a dark reddish-brown colour, but acquires a bright red hue on exposure to the air. Sometimes, however, the substance of the spleen is paler, and has a greyish aspect. It also varies in density, being occasionally rather solid, though friable. The substance of the organ consists of a reticular framework of whitish elastic bands or *trabeculæ*, of an immense proportion of blood-vessels, the larger of which run in elastic canals, and of a peculiar intervening pulpy substance, besides lymphatic vessels and nerves.

The *peritoneal* coat is thin, smooth, and firmly adherent to the elastic tunic beneath, but it may be detached by careful dissection, commencing at the borders of the hilus. It closely invests the surface of the organ, except at the places of its reflection to the stomach and diaphragm, and at the hilus.

The *proper* tunic, much thicker and stronger than the serous, is whitish in

colour and highly elastic. It cannot be raised from the spleen, because it is bound down by the trabeculæ of the substance, with the superficial bands of which it is continuous. Along the hilus this coat is reflected into the interior of the spleen, in the form of elastic sheaths or canals, which surround or include the large blood-vessels and nerves, and their principal branches. These sheaths ramify with the vessels which they include, and their finer subdivisions are continuous with the trabecular structure. The arrangement of the elastic sheaths and trabeculæ may be easily displayed by pressing and washing out the pulp from a section of the spleen; and then they are seen to form a close reticulation through the substance. Thus,

Fig. 619.

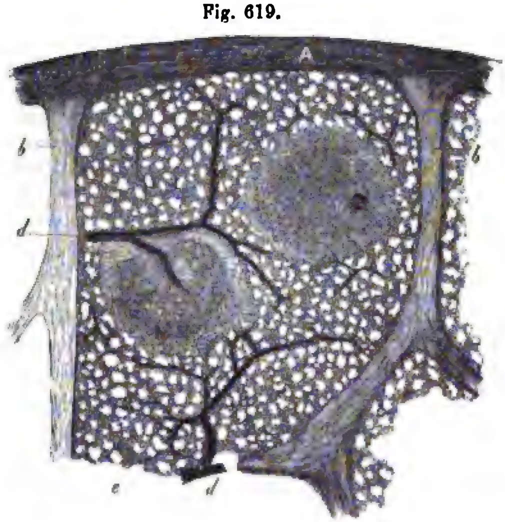


Fig. 619.—Vertical Section of a Small Superficial Portion of the Human Spleen (from Kölliker). $\frac{1}{38}$

A, peritoneal and fibrous covering; *b*, trabeculæ; *cc*, Malpighian corpuscles, in one of which an artery is seen cut transversely, in the other longitudinally; *d*, injected arterial twigs; *e*, spleen-pulp, with the venous spaces and the finest spleen tissue, the venous spaces all completely full of blood and somewhat wider than natural.

the proper coat, the sheaths of the vessels, and the trabeculæ, all of a highly elastic nature, constitute a distensible framework, which contains in its interstices or areolæ the vessels and the red pulpy substance of the spleen.

Fig. 620.

Fig. 620.—Section of Hardened Spleen-Substance (from Kölliker after a preparation by Billroth). $\frac{1}{78}$

The spleen had been hardened in chromic acid and alcohol. *a*, Malpighian bodies, one of them having an artery dividing into three twigs within, the other with two arteries cut through; *b*, trabeculæ; *c*, artery; in the remaining parts the clear spaces are the capillary veins of Billroth, the darker ones are the smallest trabeculæ of the spleen-substance.

These fibrous structures are all composed of interlaced bundles of areolar tissue mixed with a large amount of fine elastic tissue. In addition to these elements, in the spleen of the pig, the dog, and the

cat, and to a smaller extent in that of the ox and sheep, there has been found an abundant admixture of plain muscular fibres, resembling those of the middle coat of arteries. Meissner and W. Müller affirm that they also find muscular fibres in the trabeculæ and fibrous coat of the human spleen; but the existence of such fibres is denied by other observers. The elasticity of the fibrous coat and trabeculæ, together with whatever amount of muscularity they may possess, renders the spleen capable of the great and sudden alterations in size to which it is subject.

The *pulp* of the spleen is of a dark reddish-brown colour: when pressed out from between the trabeculæ it resembles grumous blood, and, like that fluid, it acquires a brighter hue on exposure to the air. This pulpy substance lies altogether outside the veins, between the branches of the venous plexus. As shown by the microscope, it consists chiefly of numerous rounded granular bodies, which have a reddish colour, and are about the size of the blood corpuscles. Their cohesion is very slight, and the terminal tufts of the arterial system of vessels are spread out amongst them. In examining the substance of the spleen, elongated caudate corpuscles are seen in rather large numbers. And besides these there are round, nucleated cells, and free nuclei. There are also large cells, some of which are nucleated, and others not, but both of which contain blood corpuscles in various states of change.

The splenic artery and vein, alike remarkable for their great proportionate size, having entered the spleen by six or more branches, ramify in its interior, enclosed within the elastic sheaths already described. The smaller branches of the arteries run along the trabeculæ, and terminate in the proper substance of the spleen in small tufts of capillary vessels arranged in pencils. These are supported by fine microscopic trabeculæ which run through the pulp in all directions. The main branches of artery which enter the spleen appear to have few or no anastomoses within the substance of the organ, for it has been justly remarked that if one of them be injected, the material of injection will return by the corresponding vein before spreading to other parts of the spleen: and it only returns by the vein after injection of the pulp. The veins, which greatly exceed the arteries in size, anastomose frequently together, so as to form a close venous plexus, placed in the intervals between the trabeculæ, and supported by them. There is still great difference of opinion as to the manner in which

Fig. 621.

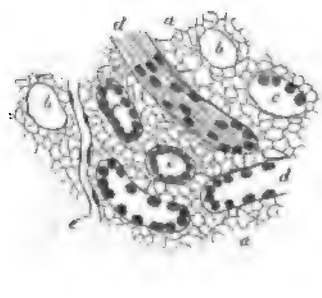


Fig. 621.—A SMALL FRAGMENT OF A PREPARED SPLEEN UNRAVELLED (from Kölliker). $\frac{1}{350}$

a, finest reticulum; *b*, transversely cut capillary veins which have lost their epithelium; *c*, veins in which the epithelium is more or less preserved; *d*, longitudinal section of the same; *e*, a capillary vessel lying in the finest splenic tissue.

the arteries and veins are connected. According to Gray, the capillaries traverse the pulp in all directions, and terminate either directly in the veins, or open into lacunar spaces, from which the veins originate. Billroth and Kölliker admit only the direct termination in veins; Stieda and W. Müller maintain that a network of intercellular passages intervenes.

Malpighian corpuscles.—On closely inspecting the surface of a section of the spleen, a number of light-coloured spots of variable size are generally seen. For the most part these are evidently the ends of divided trabeculæ or blood-vessels; but in the ox, pig, sheep, and some other animals, and also in the human subject, there are found distinct whitish vesicular-looking bodies, attached to the trabeculæ which support the small arteries, and imbedded, in groups of six or eight together, in the dark red substance of the spleen. These small vesicular bodies, the *Malpighian corpuscles of the spleen*, are capsules, varying in diameter from $\frac{1}{35}$th to $\frac{1}{60}$th of an inch, and consisting of two coats, the external of which is apparently continuous with the trabecular tissue supporting the arteries. They are filled with a soft, whitish, semi-fluid matter, which contains microscopic globules, resembling, except in colour, those composing the red pulp of the spleen. It may be remarked, that both these kinds of globules are very like the chyle corpuscles. The vesicular bodies are attached in groups to minute arterial branches; in some of the lower animals they are sessile, but in the human spleen they are pedunculated. In all cases it is established that they are expansions of the sheaths of the arteries; those which are sessile are placed usually in the angle of division of two arteries, and are formed by expansion on one side only of the vessels on which they are placed; those which are pedunculated are pierced by the artery on which they are placed, the expanded sheath having been diffused, as it were, in the capsule, round the vessel (Stieda and Henle). Their walls pass gradually into the pulp on the outside, and on the inside into the contents of the follicle (Busk and Huxley). Capillaries likewise are found within them.

Fig. 622.

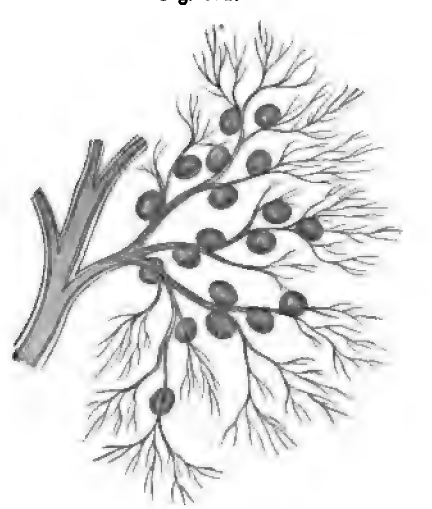


Fig. 622.—MALPIGHIAN CORPUSCLES OF THE DOG'S SPLEEN (from Kölliker). $\frac{1}{10}$

The figure shows a portion of a small artery, to one of the twigs of which the Malpighian corpuscles are attached.

The lymphatic vessels of the spleen, according to Cruikshank and Mascagni, form a superficial and a deep set. The superficial set appear as a network beneath the serous coat, receive occasional branches from the substance of the spleen, and run towards the hilus. The deep lymphatics accompany the blood-vessels, and emerge with them at the hilus, whence, communicating with the superficial set, they proceed along the gastro-splenic omentum to the neighbouring lymphatic glands: the mode in which they commence in the spleen is unknown. The lymphatics of the human spleen, at least the superficial set, are allowed by all to be very difficult to inject. But even in the domestic animals, in which the process is usually more successful, recent observers have not been so fortunate as Cruikshank and Mascagni.

The splenic *nerves* derived from the solar plexus, surround and accompany the splenic artery and its branches. They have been traced by Remak deeply into the interior of the organ.

The following works on the spleen may be referred to:—Gray, Structure and Use of the Spleen, 1854; Sanders, in Goodsir's Annals; Busk and Huxley on the Malpighian Bodies, in the Sydenham Society's translation of Kölliker's Histology; also Huxley in Micr. Jour., ii. p. 74; Billroth, in Zeitschr. f. Wissensch. Zool., xi. p. 325; W. Müller, Ueber d. fein. Bau der Milz, 1865. Stieda, in Virchow's Archiv., xxiv. p. 540, an abstract of which is given in Medico-Chir. Rev., October, 1862.

Development.—The spleen appears in the fœtus, about the seventh or eighth week, on the left side of the dilated part of the alimentary tube or stomach, and close to the rudiment of the pancreas. By the tenth week it forms a distinct lobulated body placed at the great end of the stomach. After birth it increases rapidly in size; and in a child a few weeks old, it has attained the same proportional weight to the body as in the adult. This organ is peculiar to vertebrate animals.

ORGANS OF RESPIRATION.

The organs of respiration consist of the thorax (already described), the larynx, the trachea, and the lungs. The larynx, affixed to the upper end of the windpipe, is not only the entrance for air into the respiratory organs from the pharynx, but also the organ of voice, and will be described later.

THE TRACHEA AND BRONCHI.

The *trachea* or *windpipe*, the common air passage of both lungs, is an open tube which commences at the larynx above, and divides below into two smaller tubes, the right and the left bronchus, one for each lung.

The trachea is placed in the middle plane of the body, and extends from the lower border of the cricoid cartilage of the larynx, on a level with the fifth cervical vertebra in the neck, to a place opposite the third dorsal vertebra in the thorax, where it is crossed in front by the arch of the aorta, and at or immediately below that point it bifurcates into the two bronchi. It usually measures from four inches to four inches and a half in length, and from three-quarters of an inch to one inch in width; but its length and width are liable to continual variation, according to the position of the larynx and the direction of the neck; moreover it usually widens a little at its lower end, and its diameter is always greater in the male than in the female. In front and at the sides the trachea is rendered cylindrical, firm, and resistant by a series of cartilaginous rings; these however are deficient behind, so that the posterior portion is flattened and entirely membranous.

The trachea is nearly everywhere invested by a loose areolar tissue, abounding in elastic fibres, and it is very movable on the surrounding parts. Both in the neck and in the thorax, it rests behind against the œsophagus, which intervenes between it and the vertebral column, and towards its lower part projects somewhat to its left side. The recurrent laryngeal nerves ascend to the larynx on each side in the angle between these two tubes.

In the neck the trachea is situated between the common carotid arteries: at its upper end it is embraced by the lateral lobes of the thyroid body, the middle part or isthmus of which lies across it just below the larynx. It is covered in front by the sterno-thyroid and sterno-hyoid muscles, between which, however, there is left an elongated lozenge-shaped interval in the middle line: this interval is covered in by a strong process of the deep cervical fascia, while, more superficially, another layer not so strong crosses between the sterno-mastoid muscles. The inferior thyroid veins and the *arteria thyroidea ima*, when that vessel exists (p. 340), also lie upon its anterior surface; whilst at the root of the neck, in the episternal notch, the innominate artery and the left carotid pass obliquely over it as they ascend to gain its sides.

In the thorax, the trachea is covered by the first piece of the sternum,

together with the sterno-thyroid and sterno-hyoid muscles; lower down, by the left innominate vein, then by the commencement of the innominate artery and left carotid, which pass round to its sides; next by the arch of the aorta and the deep cardiac plexus of nerves, and quite at its bifurcation, by the extremity of the pulmonary artery, where it divides into its right and left branches. Placed between the two pleuræ, the trachea is contained in the posterior mediastinum, and has on its right side the pleura and pneumogastric nerve, and on the left, the left carotid artery, the pneumo-gastric and its recurrent branch, together with some cardiac nerves.

Fig. 623.

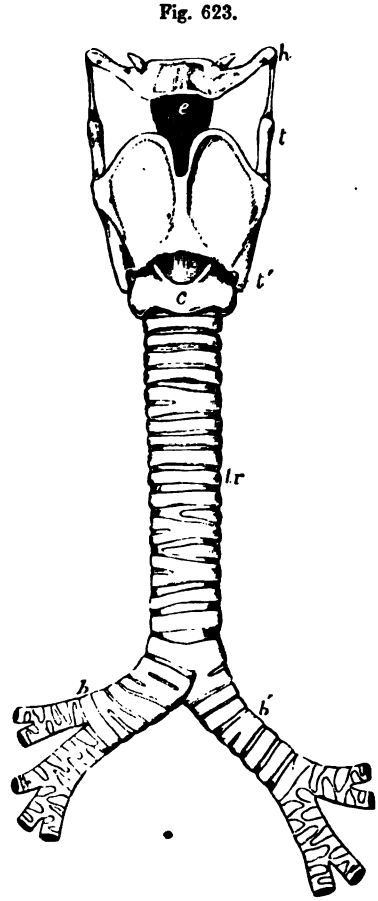


Fig. 623.—Outline showing the General Form of the Larynx, Trachea, and Bronchi, as seen from before. ½

h, the great cornu of the hyoid bone; *e*, epiglottis; *t*, superior, and *t′*, inferior cornu of the thyroid cartilage; *c*, middle of the cricoid cartilage; *tr*, the trachea, showing sixteen cartilaginous rings; *b*, the right, and *b′*, the left bronchus.

The *right and left bronchi* commence at the bifurcation of the trachea and diverge to reach the corresponding lungs. They differ from each other in length, width, direction, and connection with other parts. The *right* bronchus, wider but shorter than the left, measuring about an inch in length, passes outwards almost horizontally into the root of the right lung on a level with the fourth dorsal vertebra: it is embraced above by the vena azygos, which hooks forwards over it, to end in the vena cava superior; the right pulmonary artery lies at first below it and then in front of it. The *left* bronchus, smaller in diameter, but longer than the right, being nearly two inches in length, inclines obliquely downwards and outwards beneath the arch of the aorta to reach the root of the left lung, which it enters on a level with the fifth dorsal vertebra, that is, about an inch lower than the right bronchus. The left bronchus crosses in front of the œsophagus and descending aorta: the arch of the aorta turns backwards and to the left over it, and the left pulmonary artery lies first above it and then on its anterior surface. The remaining connections of each bronchus, as it lies within the root of the corresponding lung, and the mode in which it subdivides there into bronchia, will be hereafter described.

In form the bronchi exactly resemble the trachea on a smaller scale;

they are rounded and firm in front and at the sides, where they are provided with imperfect cartilaginous rings, and they are flattened and membranous behind.

Structure of the Trachea.

The trachea presents for consideration the elastic framework of incomplete cartilaginous rings, layers of fibrous, muscular, and elastic substance, and the lining mucous membrane, with glands.

The *cartilages* and *fibrous membrane*.—The cartilages are from sixteen to twenty in number. Each presents a curve of rather more than two-thirds of a circle, resembling the letter C. The depth from above downwards is from one line and a half to two lines, and the thickness half a line. The outer surface of each is flat, but the inner surface is convex from above downwards, so as to give greater thickness in the middle than at the upper and lower edge. The cartilages are held together by a strong fibrous membrane. This membrane is elastic aud extensible in a certain degree, and not only occupies the intervals between the cartilages, but is prolonged over their outer and inner surfaces, so that they are, as it were, imbedded in it.

Fig. 624.

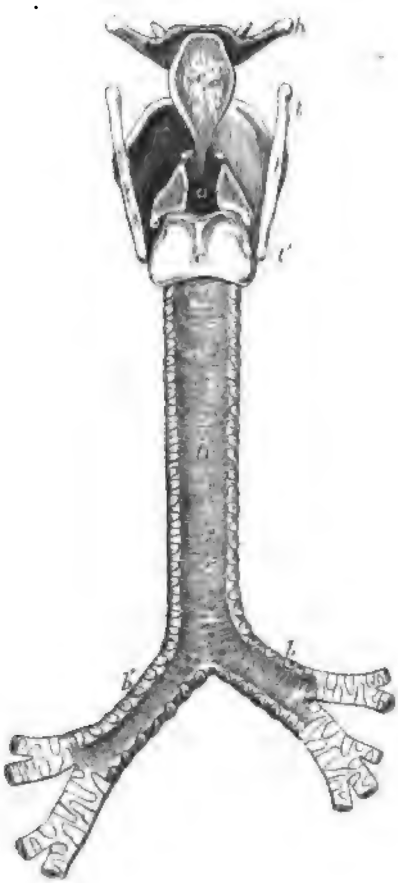


Fig. 624.—Outline showing the General Form of the Larynx, Trachea, and Bronchi as seen from behind. ½

h, great cornu of the hyoid bone ; *t*, superior, and *t'*, the inferior cornu of the thyroid cartilage ; *e*, the epiglottis; *a*, points to the back of both the arytenoid cartilages, which are surmounted by the cornicula ; *c*, the middle ridge on the back of the cricoid cartilage ; *tr*, the posterior membranous part of the trachea ; *b*, *b'*, right and left bronchi.

The layer covering the outer side of the rings is stronger than that within them, and from this circumstance, together with the roundness of their inner surfaces, they may be felt more prominently on the interior than on the exterior of the trachea.

The cartilages terminate abruptly behind. At the back of the trachea, where they are altogether wanting, the fibrous membrane is continued across between their ends, but it is here looser in its texture.

The first or highest cartilage, which is connected by the fibrous membrane with the lower margin of the cricoid cartilage, is broader than the rest, and is often divided at one end. Sometimes it coalesces in a greater or less extent with the cricoid or with the succeeding cartilage. The lowest cartilage, placed at the bifurcation of the trachea into the bronchi, is peculiar in shape; its lower border being prolonged downwards, and at the same time bent backwards so as to form a curved projection between the two bronchi. The cartilage next above this is slightly widened in the middle line. Sometimes the extremities of two adjacent cartilages are united together, and not unfrequently a cartilage is divided at one end into two short branches, the opposite end of that next it being likewise bifurcated so as to maintain the parallelism of the entire series. The use of these cartilaginous hoops is to keep the trachea open, a condition essential for the free passage of air into the lungs.

Muscular fibres.—Between the fibrous and the mucous membrane at the posterior flattened part of the trachea, there is found a continuous pale reddish layer, consisting of unstriped muscular fibres which pass across, not only between the posterior extremities of the cartilages, but opposite the intervals between the rings also, and have the power of diminishing the area of the tube by approximating the ends of the cartilages. Those which are placed opposite the cartilages are attached to the ends of the rings, and encroach also for a short distance upon the adjacent part of their inner surface.

Outside the transverse fibres are some small fasciculi having a longitudinal direction. These arise, by minute tendons of elastic tissue, in part from the inner surface of the end of the tracheal rings, and in part from the external fibrous membrane.

Fig. 625.

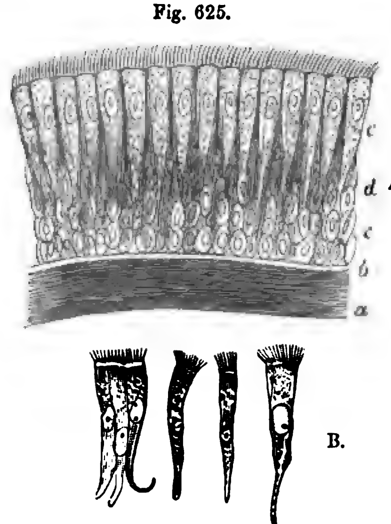


Fig. 625—Ciliated Epithelium of the Respiratory Mucous Membrane.

A, vertical section of the epithelial lining of the human windpipe (from Kölliker). $\frac{350}{1}$ *a*, *b*, subjacent membrane; *c*, lowest or spheroidal cells; *d*, middle or oval cells; *e*, superficial elongated and ciliated cells.

B, separate columnar and ciliated epithelial cells from the human nasal membrane. $\frac{300}{1}$

Elastic fibres.—Situated immediately beneath the tracheal mucous membrane, and adhering intimately to it, are numerous longitudinal fibres of yellow elastic tissue. They are found all round the tube, internal to the cartilages and the muscular layer, but are much more abundant along the posterior membranous part, where they are principally collected into distinct longitudinal bundles, which produce visible elevations or flutings of the mucous membrane. These bundles are par-

ticularly strong and numerous opposite the bifurcation of the trachea. The elastic longitudinal fibres serve to restore the windpipe to its ordinary size after it has been stretched in the direction of its length.

The *glands*.—The trachea is provided with very numerous mucous glands, the constant secretion from which serves to lubricate its internal surface. The largest of these glands are small roundish lenticular bodies, situated at the back part of the tube, lying close upon the outer surface of the fibrous layer, or occupying little recesses formed between its meshes: these are compound glands; their excretory ducts pass forwards between the muscular fibres and open on the mucous membrane, where multitudes of minute orifices are perceptible. Other similar but smaller glands are found upon and within the fibrous membrane between the cartilaginous rings. Lastly, there appear to be still smaller glands lying close beneath the mucous coat.

The *mucous membrane*.—This is smooth and of a pale pinkish white colour in health, though when congested or inflamed, it becomes intensely purple or crimson. It is covered with a ciliated columnar epithelium, the vibratile movements of which, as may be best seen at the back of the trachea of an animal, tend to drive the mucous secretion upwards towards the larynx. The epithelium is stratified, oval nucleated cells being disposed several rows deep, beneath the columnar cells which bear the cilia.

Vessels and Nerves.—The arteries of the trachea are principally derived from the inferior thyroid. The larger branches run for some distance longitudinally, and then form a superficial plexus with rounded meshes. The veins enter the adjacent plexuses of the thyroid veins. The nerves come from the trunk and recurrent branches of the pneumo-gastric, and from the sympathetic system.

Structure of the Bronchi.

The general structure of the bronchi corresponds with that of the trachea in every particular. Their *cartilaginous* rings, which resemble those of the trachea in being imperfect behind, are, however, shorter and narrower. The number of rings in the right bronchus, varies from six to eight, whilst in the left the number is from nine to twelve.

The bronchi are supplied by the bronchial arteries and veins, and the nerves are from the same source as those of the trachea.

THE LUNGS AND PLEURÆ.

The *lungs*, placed one on the right and the other on the left of the heart and large vessels, occupy by far the larger part of the cavity of the chest, and during life are always in accurate contact with the internal surface of its wall. Each lung is attached at a comparatively small part of its inner or median surface by a part named the *root*, and by a thin membranous fold which is continued downwards from it. In other directions the lung is free and its surface is closely covered by a serous membrane, belonging to itself and to the corresponding side of the thorax, and named accordingly, the right or left *pleura*.

THE PLEURÆ.

The *pleuræ* are two independent serous membranes forming two shut sacs, quite distinct from each other, which line the right and left sides of the thoracic cavity, form by their approximation in the middle line the medias-

tinal partition, and are reflected each upon the root and over the entire free surface of the corresponding lung.

Each pleura consists of a *visceral* and a *parietal* portion: the visceral portion, *pleura pulmonalis*, covers the lung; and the parietal portion lines the ribs and intercostal spaces, *pleura costalis*, covers the upper convex surface of the diaphragm, enters into the formation of the mediastinum, and is reflected on the sides of the pericardium.

The *mediastinum* or partition between the two pleural cavities, is formed by the reflection of each pleura from the anterior wall of the chest backwards on the pericardium to the root of the lung, and from the back of the root of the lung to the vertebral column. Its division into anterior, middle,

Fig. 626.

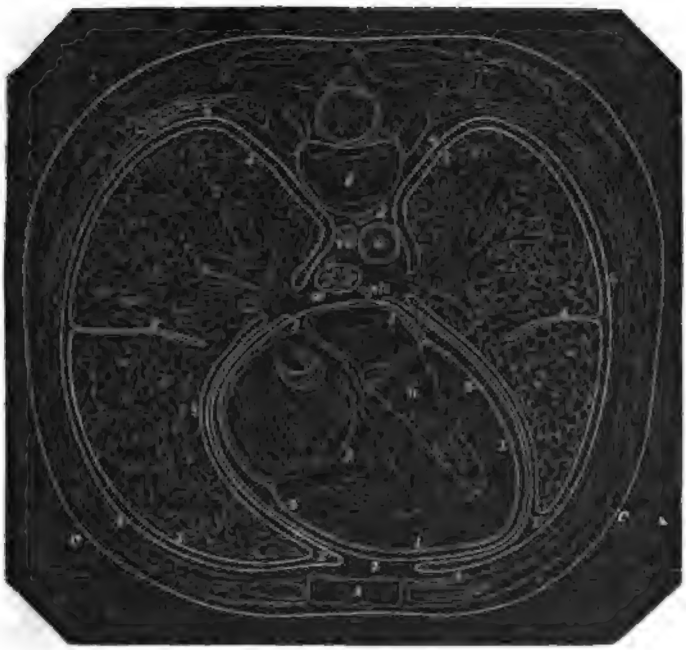


Fig. 626.—Transverse Section of the Chest of a Fœtus, illustrating the Inflections of the Pericardium and Pleuræ (after Luschka and from nature).

The sketch represents the upper surface of the lower section; the division is carried nearly in a horizontal plane on a level with the interval in front between the fifth and sixth ribs. *s*, the sternum; *c*, the body of the seventh dorsal vertebra; *h*, the right, and *h'*, the left ventricle; *œ*, the œsophagus; *p n*, the left pneumogastric nerve; near these letters respectively, the root of the right and left lungs; the right pneumogastric nerve is behind the œsophagus; *a*, the aorta; *v a*, the vena azygos; *d*, thoracic duct; 1, the cardiac pericardium; 2, the external pericardium; 2', the cavity of the pericardium; 3, the pulmonary pleura passing over the surface, and reflected at the roots of the lungs; 3', their cavity, and on the right side, the reflection at the mediastinum to the surface of the pericardium; 4, the external or costal pleuræ; *c, c*, the walls of the chest inclosing the ribs, pectoral muscles, &c.

and posterior mediastina, and the position and contents of each, have been already described (p. 297).

At the root of each lung which is enclosed by its own pleura, the visceral and parietal portions of this membrane are continuous with each other; and commencing immediately at the lower border of the root, there is found a triangular fold or duplicature of the serous membrane, extending vertically between the inner surface of the lung and the posterior mediastinum, and reaching down to the diaphragm, to which it is attached by its extremity; this fold, which serves to attach the lower part of the lung, is named *ligamentum latum pulmonis*.

The upper part of each pleura, which receives the apex of the corresponding lung, projects in the form of a cul-de-sac through the superior aperture of the thorax into the neck, reaching an inch or even an inch and a half above the margin of the first rib, and passing up under cover of the scaleni muscles,—a small slip of which, arising from the transverse process of the last cervical vertebra, is described by Sibson as expanding into a dome-like aponeurosis or fascia, which covers or strengthens the pleural cul-de-sac, and is attached to the whole of the inner edge of the first rib. The right pleura is generally stated to reach higher in the neck than the left, but in twenty observations recorded by Hutchinson, the right lung was higher in ten cases, and the left in eight, whilst in two the height was equal on the two sides. Anteriorly the pleural sacs of opposite sides come nearly or altogether into contact behind the second piece of the sternum, and continue so for some distance; but opposite the lower end of the sternum the right pleura passes beyond the middle line or remains close to it, while the left recedes to a variable distance from the sternum. Inferiorly the pleuræ do not pass quite down to the attachments of the diaphragm, but leave a portion of its circumference in contact with the costal parietes. Owing to the height of the diaphragm on the right side (corresponding with the greater convexity of the liver), the right pleural sac is shorter than the left; it is at the same time wider. According to Luschka the right pleura, opposite a line descending from the axilla, reaches down to the lower border of the ninth rib, while the left pleura in the same transverse vertical plane reaches to the lower border of the tenth rib.

Structure.—The pleura possesses the usual characters of serous membrane. The costal part of the membrane is the thickest, and may be easily raised from the ribs and intercostal spaces. It is strengthened in these situations by a layer of subserous areolar tissue of considerable thickness. On the pericardium and diaphragm the pleura is thinner and more firmly adherent; but it is thinnest and least easily detached upon the surface of the lungs.

Luschka has described nerves in this membrane, with fine and coarse fibres, which are traceable to the phrenic and sympathetic. Kölliker states that in the pleura pulmonalis of man, branches of nerves may be seen accompanying the ramifications of the bronchial arteries.

THE LUNGS.

Form.—Each lung is shaped somewhat like a cone, having its base turned downwards, and its inner side much flattened. The *base* is broad, concave, and of a semilunar form, and rests upon the arch of the diaphragm. It is bounded by a thin margin, which is received in the angle between the ribs and the diaphragm; and it reaches much lower down behind and at the outer side than in front and towards the middle line. The *apex* forms a blunted point, and, as already mentioned, reaches into the root of the neck, above the margin of the first rib, where it is separated from the first portion of the subclavian artery by the pleural membrane.

The *outer surface* of the lung, which moves upon the thoracic parietes, is smooth, convex, and of great extent, corresponding with the arches of the ribs and costal cartilages. It is of greater depth behind than in front. The *posterior* border is obtuse or rounded, and is received into the deep groove formed by the ribs at the side of the vertebral column; measured from above downwards, it is the deepest part of the lung. The *anterior* border is thin and overlaps the pericardium, forming a sharp margin, which touches the sides of the anterior mediastinum, and, opposite the middle of the sternum, is separated during inspiration from the corresponding margin of the opposite lung only by the two thin and adherent layers of the mediastinal septum. The *inner surface* is concave, and in part adapted to the convex pericardium. Upon this surface, somewhat above the middle of the lung, and considerably nearer to the posterior than the anterior border, is the *root*, where the bronchi and great vessels join the lung. Each lung is traversed by a long and deep fissure, which is directed from above and behind, downwards and forwards. It commences upon the posterior border of the lung, about three inches from the apex, and extends obliquely downwards to the anterior and inferior angle, penetrating from the outer surface to within some inches of the root of the organ. The *upper lobe*, the portion of lung which is situated above this fissure, is smaller than the portion below, and is shaped like a cone with an oblique base, whilst the *lower* and larger lobe is more or less quadrilateral. In the right lung there is a second and shorter fissure, which runs forwards and upwards from the principal fissure to the anterior margin, thus marking off a third small portion, or *middle lobe*, which appears like an angular piece separated from the anterior and lower part of the upper lobe. The left lung, which has no such middle lobe, presents a deep notch in its anterior border, into which the apex of the heart (enclosed in the pericardium) is received. This notch is formed by the rapid retreat of the anterior margin of the upper lobe from the middle line, opposite the lower half of the sternum; while inferiorly a tongue-like process of the lower lobe usually projects slightly inwards towards the middle line. Besides these differences in form which distinguish the lungs, it is to be noted that the right lung is shorter, but at the same time wider, than the left, the perpendicular measurement of the former being less, owing to the diaphragm rising higher on the right side to accommodate the liver, whilst the breadth of the left lung is narrowed, owing to the heart and pericardium encroaching on the left half of the thorax. On the whole, however, as is seen on a comparison of their weights, the right is the larger of the two lungs.

At the apices and posterior borders the extent of the lungs accurately corresponds with that of the pleural sacs which contain them, but at the anterior and inferior margins it is not so: the anterior margins pass forwards most completely between the mediastinal and costal pleura during inspiration, and retire to a variable degree from between them in expiration; and in like manner the inferior margins descend, during inspiration, between the costal and diaphragmatic pleuræ, while probably at no time do they ever descend completely to the line of reflection between those membranes.

Weight, Dimensions, and Capacity.—The lungs vary much in size and weight according to the quantity of blood, mucus, or serous fluid they may happen to contain, which is greatly influenced by the circumstances immediately preceding death, as well as by other causes. The weight of both lungs together, as generally stated, ranges from thirty to forty-eight ounces, the more prevalent weights being found between thirty-six and forty-two ounces. The proportion borne by the right lung to the left is nearly that of

twenty-two ounces to twenty, taking the combined weight of the two at forty-two ounces. The lungs are not only absolutely heavier in the male than in the female, but appear to be heavier in proportion to the weight of the body. The general ratio between the weight of the lungs and body, in the adult, fluctuates according to the estimate of Krause, between one to thirty-five and one to fifty.

The following tables, deduced from Reid's and Hutchinson's observations, show the average weight of the right and left lungs, and of both lungs together, and also the relative weight of the lungs to the body in a certain number of adults of both sexes.

AVERAGE WEIGHT IN TWENTY-NINE MALES AND TWENTY-ONE FEMALES. —(REID.)

	MALE.	FEMALE.
Right lung	24 oz.	17 oz.
Left lung	21 oz.	15 oz.
	45 oz.	32 oz.

AVERAGE IN TWENTY-FIVE MALES AND THIRTEEN FEMALES,—(REID AND HUTCHINSON.)

	MALE.	FEMALE.
Proportionate weight of the lungs to the body	1 to 37	1 to 43

The *size* and *cubical* dimensions of the lungs are influenced so much by their state of inflation, and are therefore so variable, that no useful application can be made of many of the statements given as to these measurements. It is important, however, to ascertain the quantity of *air* which they contain under different conditions. This subject has been investigated by many inquirers, whose statements on this point, however, are exceedingly various. The volume of air contained in the lungs after a forced expiration, has been estimated by Goodwyn at 109 cubic inches. After an ordinary expiration it would seem that at least 60 cubic inches more are retained in the chest, giving a total of 170 cubic inches in that condition of the lungs. The amount of air inhaled and expelled in ordinary breathing has been very differently estimated by different observers; it is most probably from 16 to 20 cubic inches. According to the extensive researches of Hutchinson, men of mean height, between five and six feet, after a complete inspiration, expel from the chest, by a forced expiration, on an average, 225 cubic inches of air, at a temperature of 60°. This quantity is called by Hutchinson the *vital capacity* of the lungs. If to it be added the average quantity found by Goodwyn to be retained in the lungs after complete expiration, viz. 109 cubic inches, the result will yield 334 cubic inches of air at 60°, as the average total capacity of the respiratory organs for air in an adult male of ordinary height.

The *vital capacity* (or difference between extreme expiration and extreme inspiration) is found by Hutchinson to bear a very uniform relation to the height of the individual, increasing at the rate of eight cubic inches for every additional inch of stature above five feet. Its relations with the *weight* of the body are not thus regularly progressive, for it appears to increase about one cubic inch for each additional pound between the weights of 105 lb. and 155 lb., or 7½ stones and 11 stones, and to decrease at a similar rate between the weights of 11 and 14 stones, or 155 and 200 lbs. From the age of 15 to 35 years the vital capacity continues to advance with the growth and activity of the frame, but between the ages of 35 and 65 it diminishes at the rate of upwards of 1 cubic inch per annum. This differential or vital capacity is by no means in proportion to the size of the thorax, whether that be estimated by the circumference of the chest, or by the sectional area of its base, or by its absolute capacity, as ascertained by measuring its cubical contents after death. It is found rather, that the vital capacity is strictly commensurate with the extent of the thoracic movements, and with the integrity of the lungs themselves; so that in phthisis, for example, it becomes reduced by a quantity varying from 10 to 70 per cent., according to the stage of the disease. A change from the erect to the sitting posture is accompanied by a diminution of the vital capacity, which in one case fell from 260 to 255 cubic inches, and on lying down, it was farther diminished to 230 cubic inches in the supine, and 220 cubic inches in the prone position of the body. Lastly, it is lowered by from 12

to 20 cubic inches by the presence of a full meal in the stomach. (Hutchinson, in Journal of Statistical Society, August, 1844; and in Medico-Chirurg. Transactions, vol. xxix., 1846; also, in the article "Thorax," in Cyclopædia of Anatomy and Physiology, and the article "Respiration," by Reid, in the same.)

Texture and consistence.—The substance of the lung is of a light porous spongy structure, and, when healthy, is buoyant in water: but in the fœtus, before respiration has taken place, and also in certain cases of congestion, collapse, or consolidation from disease, the entire lungs, or portions of them, sink in that fluid. The specific gravity of a healthy lung, as found after death, varies from 345 to 746, water being 1000. When the lung is fully distended its specific gravity is 126, whilst that of the pulmonary substance, entirely deprived of air, is 1056. (Krause.) When pressed between the fingers, the lungs impart a crepitant sensation, which is accompanied by a peculiar noise, both effects being caused by the air contained in the tissue. On cutting into the lung, the same crepitation is heard, and there exudes from the cut surface a reddish frothy fluid, which is partly mucus from the air tubes and air cells, and partly a serous exudation, tinged with blood, and rendered frothy by the admixed air. This fluid escapes in largest quantity from the posterior portion of the lung.

The pulmonary tissue is endowed with great elasticity, in consequence of which the lungs collapse to about one-third of their bulk, when the thorax is opened, and the resistance offered by the walls of that cavity to the atmospheric pressure on their outer surface is in this way removed. Owing to this elasticity also, the lungs, if artificially inflated out of the body, contract to their previous volume, when the air is again allowed to escape.

Colour.—In infancy the lungs are of a pale rose-pink colour, which might be compared to blood-froth; but as life advances they become darker, and are mottled or variegated with spots, patches, and streaks of dark slate colour, which sometimes increase to such a degree as to render the surface almost uniformly black.

The dark colouring matter found in these streaks is in the form of granules and collections of granules, not inclosed in cells; it is deposited in the interstitial areolar tissue mostly near the surface of the lung, and is not found so abundantly in the deeper substance. It exists sometimes in the air cells, and on the coats of the larger vessels. Its quantity increases with age, and is said to be less abundant in females than in males. In persons who follow the occupation of quarriers, more especially colliers, the lungs are often intensely charged with black matter. The black colouring substance of the lung seems to be composed of a mixture of carbon and some animal matter. A black substance of precisely the same nature is found in the bronchial glands. In exceptional cases the adult lungs are found with only very slight streaks of pigment.

Root of the Lung.

The root of each lung is composed of the bronchus and the large blood-vessels, together with the nerves, lymphatic vessels, and glands, connected together by areolar tissue, and enclosed in a sheath of the pleura.

The root of the right lung lies behind the superior vena cava and part of the right auricle, and below the azygos vein, which arches over it to enter the superior cava. That of the left lung passes below the arch of the aorta, and in front of the descending aorta. The phrenic nerve descends in front of the root of each lung, and the pneumogastric nerve behind, whilst the ligamentum latum pulmonis is continued from the lower border. The bronchus, together with the bronchial arteries and veins, the lymphatics

and lymphatic glands, are placed on a plane posterior to the great blood-vessels; the pulmonary artery lies more forward than the bronchus, and to a great extent conceals it, whilst the pulmonary veins are placed still farther in advance. The pulmonary plexuses of nerves lie on the anterior and posterior aspect of the root beneath the pleura, the posterior being the larger of the two.

The order of position of the great air-tube and pulmonary vessels from above downwards differs on the two sides; for whilst on the right side the bronchus is highest and the pulmonary artery next, on the left, the air-tube, in passing obliquely beneath the arch of the aorta, is depressed below the level of the left pulmonary artery, which is the highest vessel. On both sides the pulmonary veins are the lowest of the three sets of tubes.

Before entering the substance of the lung, the bronchus divides into two branches, an upper and a lower, one for each lobe. The lower branch is the larger of the two, and on the right side gives off a third small branch which enters the middle lobe of that lung.

The pulmonary artery also divides, before penetrating the lung to which it belongs, into two branches, of which the lower is the larger and supplies the inferior lobe. The upper of these two branches gives the branch to the middle lobe. A similar arrangement prevails in regard to the right pulmonary veins, the upper one of which is formed by branches proceeding from the superior and middle lobes of the right lung.

STRUCTURE OF THE LUNGS.

Coverings.—Beneath the serous covering, already noticed, there is placed a thin layer of *subserous* areolar membrane mixed with much elastic tissue. It is continuous with the areolar tissue in the interior of the lung, and has been described as a distinct coat under the name of the second or deeper layer of the pleura. In the lungs of many animals, such as the lion, seal, and leopard, this subserous layer forms a very strong membrane, composed principally of elastic tissue.

Lobules.—The *substance* of the lung is composed of numerous small lobules which are attached to the ramifications of the air-tubes, and are held together by those tubes, by the blood-vessels, and by an interlobular areolar tissue. These lobules are of various sizes, the smaller uniting into larger ones; they are bounded by flattened sides, and compactly fitted to each other and to the larger air-tubes and vessels of the lungs, those on the surface of the organ having bases, turned outwards, from half a line to a line in diameter. Though mutually adherent by means of fine areolar tissue, they are quite distinct one from the other, and may be readily separated by dissection in the lungs of young animals, and in those of the human fœtus. They may be regarded as lungs in miniature, the same elements entering into their composition as form the lung itself. The structure of a single lobule represents in fact that which is essential in the entire organ, each lobule, besides its investment of areolar membrane, being made up of the following constituents: the *air-tubes* and their *terminating cells*, the *pulmonary* and *bronchial* blood-vessels, with lymphatics, nerves, and interstitial areolar tissue.

Air-tubes.—The principal divisions of the bronchi, as they pass into the lungs, divide into tubes of less calibre, and these again subdivide in succession into smaller and smaller *bronchial* tubes, or *bronchia*, which, diverging in all directions, never anastomose, but terminate separately in the pulmonary parenchyma. The prevailing form of division is dichotomous;

but sometimes three branches arise together, and often lateral branches are given off at intervals from the sides of a main trunk. The larger branches diverge at rather acute angles, but the more remote and smaller ramifications spring less and less acutely. After a certain stage of subdivision each bronchial tube is reduced to a very small size, and, forming what has been termed *a lobular bronchial tube*, enters a distinct pulmonary lobule, within which it undergoes still farther division, and at last ends in the small cellular recesses named *air-cells* or *pulmonary cells.*

Within the lungs the air-tubes are not flattened behind like the bronchi and trachea, but form completely cylindrical tubes. Hence, although they contain the same elements as the larger air passages, reduced gradually to a state of greater and greater tenuity, they possess certain peculiarities of structure. Thus, the *cartilages* no longer appear as imperfect rings running only upon the front and lateral surfaces of the air-tube, but are scattered over all sides of the tube in the form of irregularly shaped plates of various sizes. These are most developed at the points of division of the bronchia, where they form a sharp concave ridge projecting inwards into the tube. They may be traced, becoming rarer and rarer and more reduced in size, as far as bronchia only one-fourth of a line in diameter, beyond which the tubes are entirely membranous. The *fibrous* coat extends to the very smallest tubes, becoming thinner by degrees and degenerating into areolar tissue. The *mucous membrane*, which extends throughout the whole system of air passages, and is continuous with that lining the air-cells, is also thinner than in the trachea and bronchus, but it retains its ciliated columnar epithelium. The yellow longitudinal bundles of *elastic* fibres are very distinct in both the large and small bronchia, and may be followed by dissection as far as the tube can be laid open, and by the microscope into the smallest tubes. The *muscular* fibres, which in the trachea and bronchi are confined to the back part of the tube, surround the bronchial tubes with a continuous layer of annular fibres, lying inside the irregular cartilaginous plates; they are found, however, beyond the place where the cartilages cease to exist, and appear as irregular annular fasciculi even in the smallest tubes.

Fig. 627.

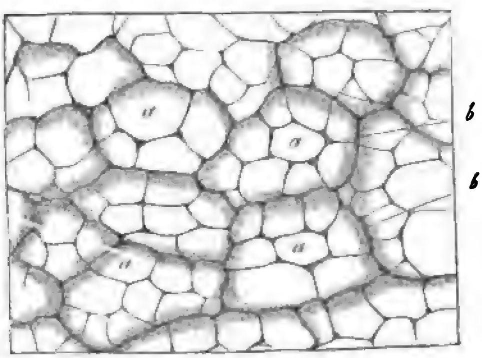


Fig. 627.—Portion of the Outer Surface of the Cow's Lung (from Kölliker after Harting). $\frac{30}{1}$

a, pulmonary vesicles filled artificially with wax; *b*, the margins of the smallest lobules or infundibula.

Air-cells or *Pulmonary vesicles.*—These cells, in which the finest ramifications of each lobular bronchial tube ultimately terminate, are in the natural state always filled with air. They are readily seen on the surface and in a section of a lung which has been inflated with air and dried;

also upon portions of fœtal or adult lung injected with mercury. In the lungs of some animals, as of the lion, cat, and dog, they are very large, and are distinctly visible on the surface of the organ. In the adult human lung their most common diameter is about $\frac{1}{100}$th of an inch, but it varies from $\frac{1}{150}$th to $\frac{1}{70}$th of an inch; they are larger on the surface than in the interior, and largest towards the thin edges of the organ: they are also said to be very large at the apex of the lung. Their dimensions go on increasing from birth to old age, and they are larger in men than in women. In the infant their diameter is usually under $\frac{1}{200}$th of an inch.

The small bronchial tube entering each lobule divides and subdivides from four to nine times, according to the size of the lobule; its branches, which diverge at less and less acute angles, at first diminish at each subdivision, but afterwards continue stationary in size, being from $\frac{1}{50}$th to $\frac{1}{30}$th of an inch in diameter. They lose at last their cylindrical form, and are converted into irregular *lobular passages*, beset, at first sparingly, but afterwards closely and on all sides, with numerous little recesses or dilatations, and ultimately terminate near the surface of the lobule in a group of similar recesses. These small recesses, whether seated along the course or at the

Fig. 628.

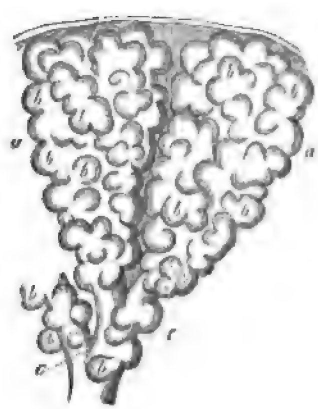


Fig. 628.—Semidiagrammatic representation of Two Small Lobuli from near the Surface of the Lung of a New-Born Child (from Kölliker). $\frac{25}{1}$

a, exterior of the two lobuli or infundibula; *b*, pulmonary vesicles or alveoli on these and on *c*, the smallest bronchial ramifications.

extremity of an air passage, are the *air-cells* or *alveoli*; and each group of alveoli with the comparatively large passage between them constitutes an *infundibulum*, so called from the manner in which it dilates from the extremity of the bronchial tube. The arrangement of these finest air passages and air cells closely resembles, though on a smaller scale, the reticulated structure of the tortoise's lung, in which large open passages lead in all directions to clusters of wide alveoli, separated from each other by intervening septa of various depths.

At the point where the small bronchial tubes lose their cylindrical character, and become covered on all sides with the cells, their structural elements also undergo a change. The *muscular* layer disappears, the longitudinal elastic bundles are broken up into an interlacement of *areolar* and *elastic tissue*, which surrounds the tubes and forms the basis of their walls. The *mucous* membrane becomes exceedingly delicate, consisting merely of a thin transparent membrane, covered by a stratum of squamous instead of ciliated cylindrical epithelium.

The walls of the alveoli, their orifices, and the margins of the septa, are supported and strengthened by scattered and coiled elastic fibres, in addition to which, according to Moleschott, Gerlach, and Hirschmann, there is likewise an intermixture of muscular fibres. It was stated by Rainey, and corroborated by Todd and Bowman, and it is still maintained by Henle, Luschka, and others, that the alveoli are destitute of all epithelium. The

presence of nuclei, however, situated in the capillary meshes, and of larger size than those which belong to the capillary walls, is allowed on all hands; and the majority of recent observers declare the existence of exceedingly

Fig. 629.

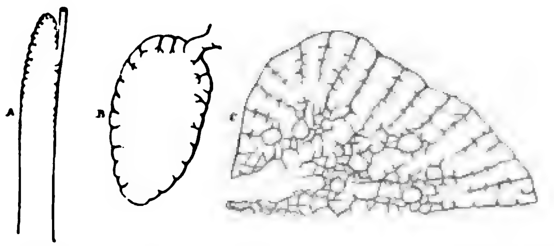


Fig. 629.—Diagrams Illustrating the Progressive Advance in the Cellular Structure of the Lungs of Reptiles.

A, the upper portion of the lung of a serpent: the summit has cellular walls, the lower part forms merely a membranous sac. B, lung of the frog, in which the cellular structure extends over the whole internal surface of the lung, but is more marked at the upper part. C, lung of the turtle: the cells here have extended so as to occupy nearly the whole thickness of the lung.

delicate squamous epithelial cells. These, according to Eberth, lie in the capillary meshes, from one to three in each, but leave the surfaces of the capillary vessels uncovered. According to others they join each other over the capillary blood-vessels.

Fig. 630.

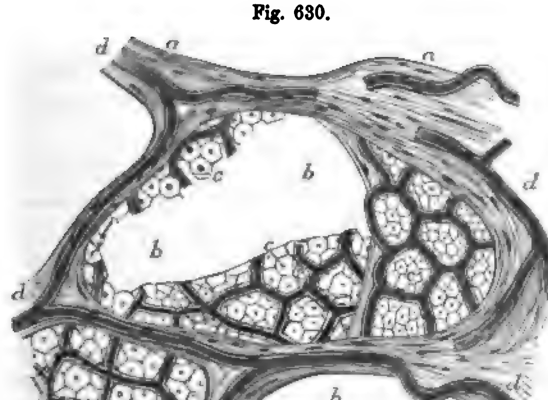


Fig. 630.—Fragment of the Injected Lung of a Young Pig, showing the Minute Structure of the Vesicles (from Hirschmann and Chrzonszczewsky).

a, the areolar and elastic tissue supporting the vesicles; *b*, the cavities of two of the vesicles partially cut through; *c*, the meshes of the pulmonary capillaries, the latter being filled with dark colouring matter, and the meshes being occupied by regular hexagonal epithelial cells, which in various places are seen to meet each other over the capillary vessels; *d*, the intervesicular pulmonary vessels. In this instance the cells observed in each mesh have been more numerous than they are said by Eberth to be in the human subject.

The following writers, among others, maintain the existence of epithelium in the air-cells: Addison, in Phil. Trans., 1842; Rossignol, Recherches sur la Structure intime du Poumon, 1846; Kölliker, in his Gewebelehre; Eberth, in Virchow's Archiv., xxiv. p. 503; and Julius Arnold, in Virchow's Archiv. xxviii. p. 433; Hirschmann, in the same, xxxvi. with addition and drawings by Chrzonszczewsky. The following are among those who deny the existence of epithelium:—Rainey, in Med.-Chir. Trans., vol. xxviii., 1845; and in Brit. and For. Med.-Chir. Review, 1855; Radclyffe Hall. in Med.-Chir. Review, July, 1857; Waters, Anatomy of the Human Lung, 1860; Luschka and Henle, in their works on Human Anatomy; Badoky, in Virchow's Archiv., xxxiii. p. 264.

Fig. 631.

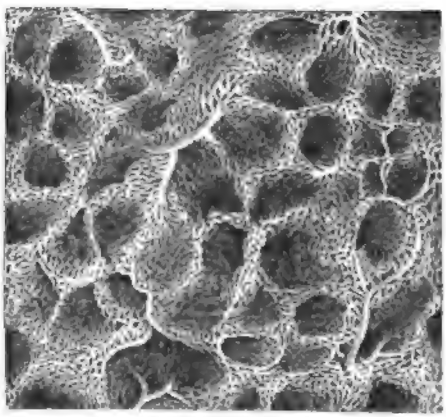


Fig. 631.—Capillary Network of the Pulmonary Bloodvessels in the Human Lung (from Kölliker). $\frac{60}{1}$

The *capillary* network of the pulmonary vessels is spread beneath the thin transparent mucous membrane of both the terminal and lateral air-cells, and is found wherever the finest air tubes have lost their cylindrical character, and become beset with cells. Around the exterior of each cell there is an arterial circle, which communicates freely with similar neighbouring circles, the capillary systems of ten or twelve cells being thus connected together, as may be seen upon the surface of the lung. From

Fig. 632.

Fig. 632.—Capillary Network on the Pulmonary Vesicles of the Horse (from Frey after a preparation by Gerlach). $\frac{0}{1}$

a, the capillary network; *b*, the terminal branches of the pulmonary artery passing towards and surrounding in part each pulmonary vesicle.

these circular vessels, which vary in diameter from $\frac{1}{1270}$th to $\frac{1}{845}$th of an inch, the capillary network arises, covering the bottom of each cell, ascending also between the duplicature of mucous membrane in the intercellular septa, and surrounding the openings of the cells. As was pointed out by Rainey, the capillary network, where it rises into the intercellular partitions, although it forms a double layer in the lungs of reptiles, is single in the lungs of man and mammalia.

The capillaries are very fine, the smallest measuring, in injected specimens, from $\frac{1}{3540}$th to $\frac{1}{3000}$th of an inch; the network is so close that the meshes

are scarcely wider than the vessels themselves. Those which lie nearest to the mouths of the alveoli are observed arching and coiled over and through the elastic fibres found in the interalveolar septa (Luschka and Badoky). The coats of the capillaries are also exceedingly thin, and thus more readily allow of the free exhalation and absorption of which the pulmonary cells are the seat.

The *branches of the pulmonary artery* accompany the bronchial tubes, but they subdivide more frequently, and are much smaller, especially in their remote ramifications. They ramify without anastomoses, and at length terminate upon the walls of the air-cells and on those of the bronchia in a fine and dense *capillary network,* from which the radicles of the *pulmonary veins* arise. The smaller branches of these veins, especially near the surface of the lung, frequently do not accompany the bronchia and arterial branches (Addison, Bourgery), but are found to run alone for a short distance through the substance of the organ, and then to join some deeper vein which passes by the side of a bronchial tube, uniting together, and also forming, according to Rossignol, frequent lateral communications. The veins coalesce into large branches, which at length accompany the arteries, and thus proceed to the root of the lung. In their course through the lung, the artery is usually found above and in front of a bronchial tube, and the vein below.

The pulmonary vessels differ from the systemic in regard to their contents, inasmuch as the artery conveys dark blood, whilst the veins carry red blood. The pulmonary veins, unlike the other veins of the body, are not more capacious than their corresponding arteries; indeed, according to Winslow, Santorini, Haller, and others, they are somewhat less so. These veins have no valves. Lastly, it may be remarked, that whilst the arteries of different lobules are independent, their veins freely anastomose together.

The bronchial vessels.—The bronchial *arteries* and *veins,* which are much smaller than the pulmonary vessels, carry blood for the nutrition of the lung, and are doubtless also the principal source of the mucous secretion found in the interior of the air-tubes, and of the thin albuminous fluid which moistens the pleura pulmonalis.

The *bronchial arteries,* from one to three in number for each lung, arise from the aorta, or from an intercostal artery, and follow the divisions of the air-tubes through the lung. They are ultimately distributed in three ways: (1) many of their branches ramify in the bronchial lymphatic glands, the coats of the large blood-vessels, and in the fibrous and muscular walls of the large and small air-tubes, and give supply to a copious capillary plexus in the bronchial mucous membrane, which in fine bronchial tubes is continuous with that supplied by the pulmonary artery; (2) others form plexuses in the interlobular areolar tissue; (3) branches spread out upon the surface of the lung beneath the pleura, forming plexuses and a capillary network, which may be distinguished from those of the pulmonary vessels of the superficial air-cells by their tortuous course and open arrangement, and also by their being outside the investing membrane of the lobules, and by ultimately ending in the branches of the *superficial* set of *bronchial veins.*

The *bronchial veins* have not quite so large a distribution in the lung as the bronchial arteries, since part of the blood carried by the bronchial arteries is returned by the pulmonary veins. The superficial and deep bronchial veins unite at the root of the lung, opening on the right side into the vena azygos, and on the left usually into the superior intercostal vein.

The *absorbent vessels* of the lungs have been already sufficiently described (p. 496).

Nerves.—The lungs are supplied with nerves from the anterior and posterior pulmonary plexuses (pp. 623, 693). These are formed chiefly by branches

from the pneumogastric nerves, joined by others from the sympathetic system. The fine nervous cords enter at the root of the lung, and follow the air-tubes. Their final distribution requires further examination. According to Remak, whitish filaments from the par vagum follow the bronchia as far nearly as the surface of the lung, and greyish filaments, proceeding from the sympathetic, and having very minute ganglia upon them in their course, pass both to the bronchia and pleura. Julius Arnold has discovered remarkable bell-shaped ganglionic corpuscles terminating the pulmonary nerves of the frog. (Virchow's Archiv., vol xxviii. p. 453.)

DEVELOPMENT OF THE LUNGS AND TRACHEA.

The lungs first appear as two small protrusions upon the front of the œsophageal portion of the alimentary canal, completely hid by the rudimentary heart and liver. These primitive protrusions or tubercles are visible in the chick on the third day of incubation, and in the embryos of mammalia and of man at a corresponding stage of advancement. Their internal cavities communicate with the œsophagus, and are lined by a prolongation of its inner layer. At a later period they are connected with the œsophagus by means of a long pedicle, which ultimately forms the trachea, whilst the bronchia and air-cells are developed by the progressive ramification of the internal cavity in the form of cæcal tubes, after the manner of the ducts of glands. According to Kölliker, the human lung in the latter half of the second month, presents a granular appearance on the surface, produced by the primitive air-cells placed at the extremities of ramified tubes, which occupy the whole of the interior of the organ; the ramification of the bronchial twigs and multiplication of air-cells goes on increasing, and this to such an extent that the air-cells in the fifth month are only halt the size of those which are found in the fourth month.

Fig. 633.

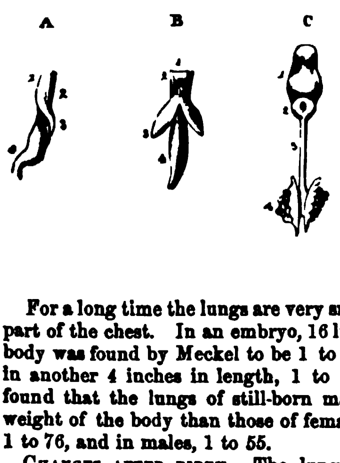


Fig. 633.—Sketch illustrating the Development of the Respiratory Organs (from Rathke.)

A, œsophagus of a chick, on the fourth day of incubation, with the rudimentary lung of the left side, seen laterally; 1, the front, and 2, the back of the œsophagus; 3, rudimentary lung protruding from that tube; 4, stomach. B, the same seen in front, so as to show both lungs. C, tongue and respiratory organs of embryo of the horse; 1, tongue; 2, larynx; 3, trachea; 4, lungs seen from behind.

For a long time the lungs are very small, and occupy only a limited space at the back part of the chest. In an embryo, 16 lines in length, their proportionate weight to the body was found by Meckel to be 1 to 25; in another, 29 lines long, it was 1 to 27; in another 4 inches in length, 1 to 41; and at the full period, 1 to 70. Huschke found that the lungs of still-born male children were heavier in proportion to the weight of the body than those of female children; the ratio being, amongst females, 1 to 76, and in males, 1 to 55.

Changes after birth.—The lungs undergo very rapid and remarkable changes after birth, in consequence of the commencement of respiration: these affect their size, position, form, consistence, texture, colour, and weight, and should be carefully studied, as furnishing the only means of distinguishing between a still-born child and one that has respired.

1. *Position, size, and form.*—In a fœtus at the full period, or in a still-born child, the lungs, comparatively small, lie packed at the back of the thorax, and do not entirely cover the sides of the pericardium; subsequently to respiration, they expand, and completely cover the pleural portions of that sac, and are also in contact with almost the

whole extent of the thoracic parietes, where it is covered with the pleural membrane. At the same time, their previously thin sharp margins become more obtuse, and their whole form is less compressed.

2. *Consistence, texture, and colour.*—The introduction of air, and of an increased quantity of blood into the fœtal lungs, which ensues immediately upon birth, converts their tissue from a compact, heavy, granular, yellowish-pink, gland-like substance, into a loose, light, rose-pink, spongy structure, which, as already mentioned, floats in water. The changes thus simultaneously produced in their consistence, colour, and texture, occur first at their anterior borders, and proceed backwards through the lungs: they, moreover, appear in the right lung a little sooner than in the left.

3. *Weight.*—The *absolute weight* of the lungs, having gradually increased from the earliest period of development to birth, undergoes at that time, from the quantity of blood then poured into them, a very marked addition, amounting to more than one-third of their previous weight: for example, the lungs before birth weigh about one and a half ounce, but, after complete expansion by respiration, they weigh as much as two and a half ounces. The *relative weight* of the lungs to the body, which at the termination of intra-uterine life is about 1 to 70, becomes, after respiration, on an average, about 1 to 35 or 40; a proportion which is not materially altered through life. Their *specific gravity* is at the same time changed from 1·056 to about ·342.

4. *Changes in the trachea after birth.*—In the fœtus the trachea is flattened before and behind, its anterior surface being even somewhat depressed; the ends of the cartilages touch; and the sides of the tube, which now contains only mucus, are applied to one another. The effect of respiration is at first to render the trachea open, but it still remains somewhat flattened in front, and only later becomes convex.

THE LARYNX, OR ORGAN OF VOICE.

The upper part of the air passage is modified in its structure to form the *organ of voice.* This organ, named the *larynx*, is placed at the upper and fore part of the neck, where it forms a considerable prominence in the middle line. It lies between the large vessels of the neck, and below the tongue and os hyoides, to which bone it is suspended. It is covered in front by the cervical fascia along the middle line, and on each side by the sterno-hyoid, sterno-thyroid, and thyro-hyoid muscles, by the upper end of the thyroid body, and by a small part of the inferior constrictor of the pharynx. Behind, it is covered by the pharyngeal mucous membrane, and above it opens into the cavity of the pharynx.

The larynx consists of a framework of cartilages, articulated together and connected by proper ligaments, two of which, named the *true vocal* cords, are more immediately concerned in the production of the voice. It also possesses muscles, which move the cartilages one upon another, and modify the form and tension of its apertures, a mucous membrane lining its internal surface, numerous mucous glands, and lastly, blood-vessels, lymphatics, and nerves, besides areolar tissue and fat.

Cartilages of the Larynx.

The cartilages of the larynx consist of three single and symmetrical pieces, named respectively the *thyroid cartilage*, the *cricoid cartilage*, and the *cartilage of the epiglottis*, and of six others, which occur in pairs, namely, the two *arytenoid cartilages*, the *cornicula laryngis*, and the *cuneiform cartilages.* In all there are nine distinct pieces, the two cornicula and two cuneiform cartilages being very small. Of these, only the thyroid and cricoid cartilages are seen on the front and sides of the larynx; the arytenoid cartilages, surmounted by the cornicula laryngis, together with the back of the cricoid cartilage, on which they rest, form the posterior wall of

the larynx, whilst the epiglottis is situated in front, and the cuneiform cartilages on each side of the upper opening.

The *thyroid* cartilage is the largest of the pieces composing the framework of the larynx. It is formed by two flat lamellæ, united in front, at an acute angle along the middle line, where they form a projection at the upper part. This angular projection is subcutaneous, and is much more prominent in the male than in the female, being named in the former the *pomum Adami*. The two symmetrical halves or lamellæ, named the *alæ*, are somewhat quadrilateral in form : the anterior border where they are joined is the shortest, the pomum Adami being surmounted by a deep notch ; the posterior free border of each, thickened and vertical, is prolonged upwards and downwards into two processes or cornua, and gives attachment to the stylo-pharyngeus and palato-pharyngeus muscles ; the superior and inferior borders are both of them concave immediately in front of the cornua, while the superior is convex in its anterior half, and the inferior is nearly straight.

The *external* flattened surface of each ala is marked by an indistinct *oblique line* or ridge, which, commencing at a tubercle situated at the back part of the upper border of the cartilage, passes downwards and forwards, so as to mark off the anterior three-fourths of the surface from the remaining posterior portion. This line gives attachment below to the sterno-thyroid, and above to the thyro-hyoid muscle, whilst the small smooth surface behind it gives origin to part of the inferior constrictor of the pharynx, and affords attachment, by means of areolar tissue, to the thyroid body. On their *internal* surfaces, the two alæ are smooth and slightly concave, and by their

Fig. 634.

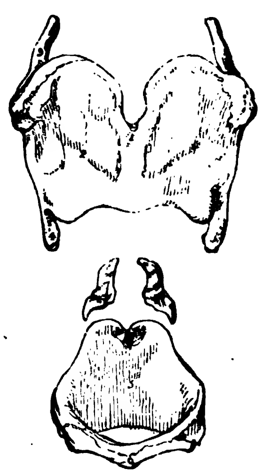


Fig. 634.—Cartilages of the Larynx seen from before. $\frac{3}{4}$

1 to 4, thyroid cartilage ; 1, vertical ridge or pomum Adami ; 2, right ala ; 3, superior, and 4, inferior cornu of the right side ; 5, 6, cricoid cartilage ; 5, inside of the posterior part ; 6, anterior narrow part of the ring ; 7, arytenoid cartilages.

union in front, form a narrow angle within. Of the four *cornua*, all of which bend inwards, the two *superior* or *great* cornua, pass backwards, upwards, and inwards, and terminate each by a blunt extremity, which is connected, by means of the lateral thyro-hyoid ligament, to the tip of the corresponding great cornu of the os hyoides. The *inferior* or *smaller* cornua, which are somewhat thicker but shorter, are directed forwards and inwards, and present each, on the inner aspect of the tip, a smooth surface, for articulation with a prominence on the side of the cricoid cartilage.

The *cricoid cartilage*, so named from being shaped like a ring, is thicker in substance and stronger than the thyroid cartilage. It is deep behind, where the thyroid cartilage is deficient, measuring in the male about an inch from above downwards ; but in front its vertical measurement is diminished to a fourth or a fifth of an inch. This diminution is caused by the direction of the superior border, which rises in convex elevation behind, and

descends with a deep concavity in front below the thyroid cartilage; while the inferior border is horizontal, and connected by membrane to the first ring of the trachea. The posterior elevated part of the upper border is slightly notched in the middle line; and on the sides of this notch are two convex oval articular facets, directed upwards and outwards, with which the arytenoid cartilages are articulated. The external surface of the cartilage is convex and smooth in front and at the sides, where it affords attachment to the crico-thyroid muscles, and behind these to the inferior constrictor muscle on each side: posteriorly it presents in the middle line a slight vertical ridge, to which some of the longitudinal fibres of the œsophagus are attached. On each side of this ridge is a broad depression occupied by the posterior crico-arytenoid muscle, and externally and anteriorly to that a small rounded and slightly raised surface for articulation on either side with the inferior cornu of the thyroid cartilage. The internal surface is in contact throughout with the mucous membrane of the larynx. The lower border of the cricoid cartilage is circular, but higher up it is somewhat compressed laterally, so that the passage through it is elliptical.

The *arytenoid cartilages* are two in number, and are of a symmetrical form. They may be compared to three-sided pyramids recurved at the summit, resting by their bases on the posterior and highest part of the cricoid cartilage, and approaching near to one another. Each measures from five to six lines in height, about three lines in width, and, in the middle of its inner surface, more than a line from before backwards. Of the three faces, the *posterior* is broad, triangular, and excavated from above downwards, lodging part of the arytenoid muscle. The *anterior*

Fig. 635.

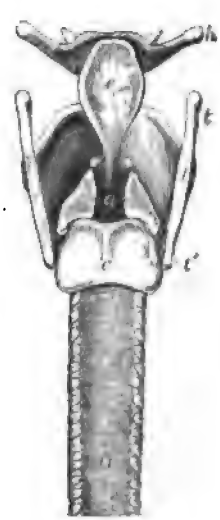


Fig. 635.—Outline showing the Position and Form of the Arytenoid Cartilages from behind. ½

h, hyoid bone; *t*, the superior, and *t'*, the inferior cornu of the thyroid cartilage; *c*, placed on the median ridge of the back of the cricoid cartilage; *a*, placed between the two arytenoid cartilages, to which the letter points by two dotted lines; the cartilages of Santorini or cornicula are shown above the upper angles; *tr*, the trachea.

surface, convex in its general outline, and somewhat rough, gives attachment to the thyro-arytenoid muscle, and, by a small tubercle, to the corresponding superior or false vocal cord. The *internal* surface, which is the narrowest of the three, and slightly convex, is nearly parallel with that of the opposite cartilage, being covered by the laryngeal mucous membrane. The anterior and posterior borders, which limit the internal face, ascend nearly in the same vertical plane, whilst the external border, which separates the anterior from the posterior surface, is directed obliquely upwards and inwards.

The base of each arytenoid cartilage is slightly hollowed, having towards its inner part a smooth surface for articulation with the cricoid cartilage. Two of its angles are remarkably prominent, viz., one *external*, short, and rounded, which projects backwards and outwards, and into which the posterior and the lateral crico-arytenoid muscles are inserted; the other *anterior*, which is more pointed, and forms a horizontal projection forwards, to which the corresponding true vocal cord is attached.

The *apex* of each arytenoid cartilage curves backwards and a little inwards, and terminates in a blunt point, which is surmounted by a small cartilaginous appendage named corniculum laryngis.

The *cornicula laryngis*, or *cartilages of Santorini*, are two small yellowish cartilaginous nodules of a somewhat conical shape, which are articulated with the summits of the arytenoid cartilages, and serve as it were to prolong them backwards and inwards. They are sometimes continuous with the arytenoid cartilages.

The *cuneiform cartilages*, or *cartilages of Wrisberg*, are two very small, soft, yellowish cartilaginous bodies, placed one on each side of the larynx in the fold of mucous membrane, which extends from the summit of the arytenoid cartilage to the epiglottis. They have a conical form, their base or broader part being directed upwards. They occasion small conical elevations of the mucous membrane in the margin of the superior aperture of the larynx, a little in advance of the cartilages of Santorini, with which, however, they are not directly connected.

The *epiglottis* is a median lamella of yellow cartilage, shaped somewhat like an ovate or obcordate leaf, and covered by mucous membrane. It is placed in front of the superior opening of the larynx, projecting, in the ordinary condition, upwards immediately behind the base of the tongue; but during the act of swallowing it is carried downwards and backwards over the entrance into the larynx, which it covers and protects.

The cartilage of the epiglottis is broad and somewhat rounded at its upper free margin, but inferiorly it becomes pointed, and is prolonged by means of a long, narrow, fibrous band (the thyro-epiglottic ligament) to the deep angular depression between the alæ of the thyroid cartilage, to which it is attached, behind and below the median notch. Its *lateral* borders, which are convex and turned backwards, are only partly free, being in part concealed within the folds of mucous membrane, which pass back on each side to the arytenoid cartilages. The *anterior* or *lingual* surface is free only in the upper part of its extent, where it is covered by mucous membrane. Lower down, the membrane is reflected from it forwards to the base of the tongue, forming one median fold and two lateral frænula, or glosso-epiglottidean ligaments. The adherent portion of this surface is also connected with the posterior surface of the os hyoides by means of a median elastic tissue named the hyo-epiglottic ligament, and is moreover in contact with some glands and fatty tissue. The posterior or *laryngéal* surface of the epiglottis, which is free in the whole of its extent, is concavo-convex from above downwards, but concave from side to side: the lower convexity projecting backwards into the larynx is named the tubercle or cushion. The epiglottis is closely covered by mucous membrane, on removing which, the yellow cartilaginous lamella is seen to be pierced by numerous little pits and perforations, in which are lodged small glands which open on the surface of the mucous membrane.

The *structure of the cartilages of the larynx*.—The epiglottis, together with the cornicula laryngis and cuneiform cartilages, are composed of what

is called yellow or spongy cartilage, which has little tendency to ossify. The structure of all the other cartilages of the larynx resembles that of the costal cartilages, like which, they are very prone to ossification as life advances.

Ligaments of the larynx.—The epiglottidean ligaments and the union of the cricoid cartilage with the trachea have been already mentioned: the other ligaments of the larynx may be divided into thyro-hyoid, crico-thyroid, and arytenoid groups.

Thyro-hyoid ligaments.—The larynx is connected with the os hyoides by a broad membrane and by two round lateral ligaments. The *thyro-hyoid membrane*, or *middle thyro-hyoid ligament*, is a broad, fibrous, and somewhat elastic membrane, which passes up from the whole length of the superior border of the thyroid cartilage to the os hyoides, where it is attached to the posterior and upper margin of the obliquely inclined inferior surface of the bone. Owing to this arrangement, the top of the larynx, when drawn upwards, is permitted to slip within the circumference of the hyoid bone, between which and the upper part of the thyroid cartilage there is occasionally found a small synovial bursa. The thyro-hyoid membrane is thick and subcutaneous towards the middle line, but on each side becomes thin and loose, and is covered by the thyro-hyoid muscles. Behind it is the epiglottis with the mucous membrane of the base of the tongue, separated, however, by much adipose tissue and some glands. It is perforated by the superior laryngeal artery and nerve of each side.

The *lateral thyro-hyoid ligaments*, placed at the posterior limits of the thyro-hyoid membrane, are two rounded yellowish cords, which pass up from the superior cornua of the thyroid cartilage, to the rounded extremities of the great cornua of the hyoid bone. They are distinctly elastic, and frequently enclose a small oblong cartilaginous nodule, which has been named *cartilago triticea:* sometimes this nodule is bony.

Crico-thyroid ligaments.—The thyroid and cricoid cartilages are connected together by a membranous ligament and synovial articulations. The *crico-thyroid membrane* is divisible into a mesial and two lateral portions. The mesial portion, broad below and narrow above, is a strong triangular yellowish ligament, consisting chiefly of elastic tissue, and is attached to the contiguous borders of the two cartilages. Its anterior surface is convex and is partly covered by the crico-thyroid muscles, and is crossed horizontally by a small anastomotic arterial arch, formed by the junction of the crico-thyroid branches of the right and left superior thyroid arteries. The lateral portions are fixed on each side to the inner lip of the upper border of the cricoid cartilage, between the deep muscles and the mucous membrane: they become much thinner as they pass upwards and backwards, and are continuous with the lower margin of the inferior or true vocal cords, becoming blended with them firmly in front.

The *crico-thyroid joints*, between the inferior cornua of the thyroid cartilage and the sides of the cricoid, are two small but distinct articulations, having each a ligamentous capsule and a synovial membrane. The prominent oval articular surfaces of the cricoid cartilage are directed upwards and outwards, while those of the thyroid cartilage, which are slightly concave, look in the opposite direction. The capsular fibres form a stout band behind the joint. The movement allowed is of a rotatory description, the thyroid cartilage revolving on its inferior cornua, and the axis of rotation passing transversely through the two joints.

Arytenoid ligaments.—The arytenoid cartilages are connected below with

the cricoid cartilage, above with the cornicula, and in front, by means of fibres contained within the true and false vocal cords, with the thyroid cartilage.

The *crico-arytenoid* articulations are surrounded by a series of thin capsular fibres, which, together with a loose synovial membrane, serve to connect the convex elliptical articular surfaces on the upper border of the cricoid cartilage with the concave articular depressions on the bases of the arytenoid cartilages. There is, moreover, a strong *posterior crico-arytenoid* ligament on each side, arising from the cricoid, and inserted into the inner and back part of the base of the arytenoid cartilage.

The summits of the arytenoid cartilages and the cornicula laryngis have usually a fibrous and synovial capsule to connect them, but it is frequently indistinct.

The *superior thyro-arytenoid* ligaments consist of a few slight fibrous fasciculi, contained within the folds of mucous membrane forming the false vocal cords hereafter to be described, and are fixed in front to the depression between the alæ of the thyroid cartilage, somewhat above its middle, and close to the attachment of the epiglottis: behind they are connected to the tubercles on the rough anterior surface of the arytenoid cartilages. They are continuous above with scattered fibrous bundles contained in the aryteno-epiglottidean folds.

The *inferior thyro-arytenoid ligaments*, placed within the lips of the glottis, and forming the true vocal cords, are two bands of elastic tissue which are attached in front to about the middle of the depression between the alæ of the thyroid cartilage, below the superior cords; and are inserted behind into the elongated anterior processes of the base of the arytenoid cartilages. These bands are of considerable strength, and consist of closely-arranged parallel fibres. They are continuous below with the thin lateral portions of the crico-thyroid membrane.

Interior of the larynx.—The cavity of the larynx is divided into an upper and a lower compartment by the comparatively narrow aperture of the glottis, or *rima glottidis*, the margins of which constitute in their two anterior thirds the lower or *true vocal cords*; and the whole laryngeal cavity, viewed in transverse section, thus presents the appearance of an hour-glass, or of two funnels meeting together by their narrower ends. The upper compartment communicates with the pharynx by the *superior aperture* of the larynx, and contains immediately above the rima glottidis the *ventricles* and the upper or *false vocal cords*. The lower compartment passes inferiorly into the tube of the windpipe without any marked constriction or limitation between them (Fig. 638).

The *superior aperture* of the larynx, by which it communicates with the pharynx, is a triangular opening, wide in front and narrow behind, the lateral margins of which slope obliquely downwards and backwards. It is bounded in front by the epiglottis, behind by the summits of the arytenoid cartilages and cornicula laryngis with the angular border of mucous membrane crossing the median space between them, and on the sides by two folds of mucous membrane named the *aryteno-epiglottidean folds*, which, enclosing a few ligamentous and muscular fibres, pass forwards from the tips of the arytenoid cartilages and cornicula to the lateral margins of the epiglottis (Fig. 637).

In studying the form of the laryngeal cavity and its apertures, it is proper to become acquainted with the appearances which they present on examination during life by means of the laryngoscope, and with the relations

of these to the anatomical structure. On thus examining the superior aperture, there are seen on each side two rounded elevations, corresponding

Fig. 636.

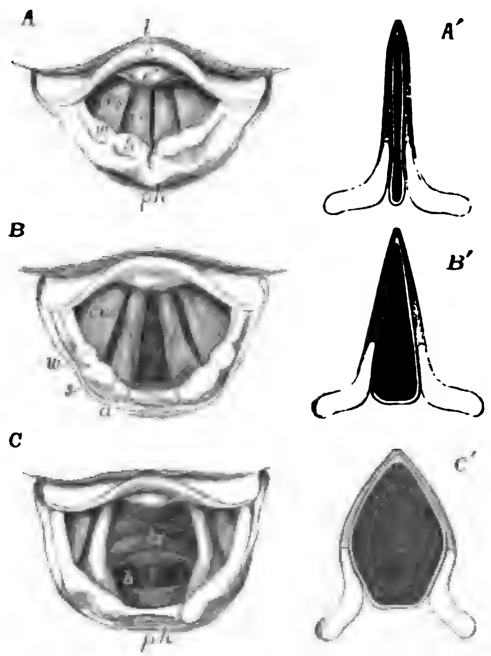


Fig. 636.—Three Laryngoscopic Views of the Superior Aperture of the Larynx and Surrounding Parts in Different States of the Glottis during Life (from Czermak).

A, the glottis during the emission of a high note in singing. B, in easy or quiet inhalation of air. C, in the state of widest possible dilatation as in inhaling a very deep breath. The diagrams A′, B′, and C′, have been added to Czermak's figures to show in horizontal sections of the glottis the position of the vocal ligaments and arytenoid cartilages in the three several states represented in the other figures. In all the figures, so far as marked, the letters indicate the parts as follows, viz.: *l*, the base of the tongue; *e*, the upper free part of the epiglottis; *e′*, the tubercle or cushion of the epiglottis; *ph*, part of the anterior wall of the pharynx behind the larynx; in the margin of the aryteno-epiglottidean fold *w*, the swelling of the membrane caused by the cartilages of Wrisberg; *s*, that of the cartilages of Santorini; *a*, the tip or summit of the arytenoid cartilages; *cv*, the true vocal cords or lips of the rima glottidis; *cvs*, the superior or false vocal cords; between them the ventricle of the larynx; in C, *tr* is placed on the anterior wall of the receding trachea, and *b* indicates the commencement of the two bronchi beyond the bifurcation which may be brought into view in this state of extreme dilatation.

respectively to the cornicula and the cuneiform cartilages; while in the middle line in front there is a tumescence of the mucous membrane of the lower part of the epiglottis, enabling that structure to close the aperture more accurately when it is depressed, and named the *tubercle* or *cushion of the epiglottis*. The mucous membrane between the arytenoid cartilages is stretched when they are separated, and folded double when they are approximated. (Czermak on the Laryngoscope, translated by the New Sydenham Society.)

On looking down through the superior opening of the larynx, the *glottis* or *rima glottidis* is seen at some distance below, in the form of a long narrow fissure running from before backwards. It is situated on a level with the lower part of the arytenoid cartilages, and is bounded by the *true vocal cords*, two smooth, strong, and straight folds of membrane projecting inwards, with their free edges directed towards the middle line. Above the glottis, another pair of projecting folds is seen, the superior or false vocal cords, which are much thinner and weaker and less projecting than the

inferior, and are arched in form. Bounded by the superior and inferior vocal cords are two deep oval depressions, one on each side of the glottis, named the *sinuses*, or *ventricles*, of the larynx ; and leading upwards from the anterior parts of these depressions, external to the superior vocal cords, are two small culs-de-sac, named the *laryngeal pouches* or *sacculi*.

Fig. 637.

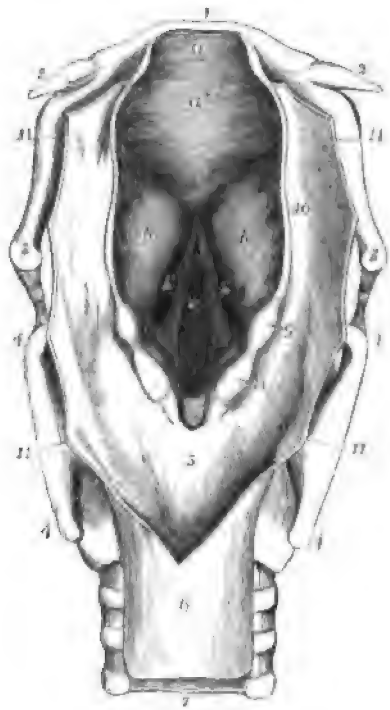


Fig. 637.—Perspective View of the Pharyngeal Opening into the Larynx from above and behind.

The superior aperture has been much dilated ; the glottis is in a moderately dilated condition ; the wall of the pharynx is opened from behind and turned to the two sides. 1, body of the hyoid bone ; 2, small cornua ; 3, great cornua ; 4, upper and lower cornua of the thyroid cartilage ; 5, membrane of the pharynx covering the posterior surface of the cricoid cartilage ; 6, upper part of the gullet ; 7, membranous part of the trachea ; 8, projection caused by the cartilage of Santorini ; 9, the same belonging to the cartilage of Wrisberg ; 10, aryteno-epiglottidean fold ; 11, cut margin of the wall of the pharynx ; *a*, free part of the epiglottis ; *a'*, its lower pointed part ; *a''*, the cushion ; *b*, eminence on each side over the sacculus or pouch of the larynx ; *b'*, the ventricles ; *c*, the glottis : the lines on each side point to the margins or vocal cords.

The *superior vocal cords*, also called the *false* vocal cords, because they are not immediately concerned in the production of the voice, are two folds of mucous membrane, each of which forms a free crescentic margin, bounding the corresponding ventricle of the larynx, the hollow of which is seen on looking down into the laryngeal cavity, from the superior vocal cords being separated farther from each other than the inferior cords.

The *inferior* or *true vocal cords*, the structures by the vibration of which the sounds of the voice are produced, occupy the two anterior thirds of the aperture of the glottis. These cords are not mere folds of mucous membrane, but are strengthened near their free margins by the elastic thyro-arytenoid ligaments, and further out by the thyro-arytenoid muscles. The mucous membrane covering them is so thin and closely adherent as to show the light colour of the ligaments through it. Their free edges, which are sharp and straight, and directed upwards, form the lower boundaries of the ventricles, and are the parts thrown . nto vibration during the production of the voice. Their inner surfaces are flattened, and look towards each other.

The *rima glottidis*, an elongated aperture, situated, anteriorly, between the inferior or true vocal cords, and, posteriorly, between the bases of the arytenoid cartilages, forms when nearly closed a long narrow slit, slightly

wider in the centre; when moderately open, as in easy respiration, its shape is that of a long triangle, the pointed extremity being directed forwards, and the base being placed behind between the arytenoid cartilages; and in its fully-dilated condition it has the figure of an elongated lozenge, the posterior sides of which are formed by the inner sides of the bases of the arytenoid cartilages, while the posterior angle is truncated. This aperture is the narrowest part of the interior of the larynx; in the adult male it measures about eleven lines or nearly an inch in an antero-posterior direction, and three or four lines across at its widest part, which may be dilated to nearly half an inch. In the female, and in males before the age of puberty, its dimensions are less, its antero-posterior diameter being about eight lines, and its transverse diameter about two. The vocal ligaments measure about seven lines in the adult male, and five in the female.

The *ventricles*, or *sinuses* of the larynx, situated between the superior and inferior vocal cords on each side, are narrower at their orifice than in their interior. The upper margin of each is crescentic, and the lower straight: the outer surface is covered by the upper fibres of the corresponding thyro-arytenoid muscle.

Fig. 638.

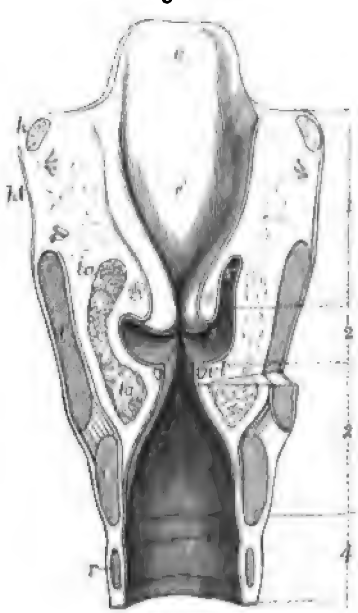


Fig. 638.—Anterior Half of a Transverse Vertical Section through the Larynx near its middle.

In order to bring the deepest part of one of the sacculi into view, the section is carried somewhat farther forward on the right side: the space between the horizontal dotted lines marked 1, comprises the upper division of the laryngeal cavity; that marked 2, corresponds to the middle cavity or that of the ventricles; that marked 3, indicates the lower division of the laryngeal cavity, continued into 4, a part of the trachea; *e*, the free part of the epiglottis; *e'*, its cushion; *h*, the divided great cornua of the hyoid bone; *ht*, thyro-hyoid membrane; *t*, cut surface of the divided thyroid cartilage; *c*, that of the cricoid cartilage; *r*, first ring of the trachea; *ta*, superior and inferior parts of the thyro-arytenoid muscle; *vl*, thyro-arytenoid ligament in the true vocal cord covered by mucous membrane at the rima glottidis; *s*, the ventricle; above this, the superior or false cords or margin of the folds above the ventricles; *s'*, the sacculus or pouch opened on the right side.

The small culs-de-sac named the *laryngeal pouches* lead from the anterior part of the ventricles upwards, for the space of half an inch, between the superior vocal cords on the inner side, and the thyroid cartilage on the outer side, reaching as high as the upper border of that cartilage at the sides of the epiglottis. The pouch is conical in shape, and curved slightly backwards. Its opening into the ventricle is narrow, and is generally limited by two folds of the lining mucous membrane. Numerous small glands, sixty or seventy in number, open into its interior, and it is surrounded by a quantity of fat. Externally to the fat, this little pouch receives a fibrous investment, which is continuous below with the superior vocal cord. Over

its laryngeal side and upper end is a thin layer of muscular fibres (compressor sacculi laryngis, arytæno-epiglottideus inferior, Hilton) connected above with those found in the aryteno-epiglottidean folds. The upper fibres of the thyro-arytenoid muscles pass over the outer side of the pouch, a few being attached to its lower part. The laryngeal pouch is supplied abundantly with nerves, derived from the superior laryngeal.

Muscles of the Larynx.

Besides certain extrinsic muscles already described—viz., the sterno-hyoid, omo-hyoid, sterno-thyroid, and thyro-hyoid muscles, together with the muscles of the supra-hyoid region, and the middle and inferior constrictors of the pharynx, all of which act more or less upon the entire larynx, there are certain *intrinsic muscles* which move the different cartilages upon one another, and modify the size of the apertures and the state of tension of the soft parts of the larynx. These intrinsic muscles are the *crico-thyroid*, the *posterior* and *lateral crico-arytenoid*, the *thyro-arytenoid*, the *arytenoid*, and the *aryteno-epiglottidean*, together with certain other slender muscular fasciculi. All these muscles, except the arytenoid, which crosses the middle line, are in pairs.

The *crico-thyroid muscle* is a short thick triangular muscle, seen on the front of the larynx, situated on the fore part and side of the cricoid cartilage. It arises by a broad origin from the cricoid cartilage, reaching from the median line backwards upon the lateral surface, and its fibres, passing obliquely upwards and outwards and diverging slightly, are inserted into the lower border of the thyroid cartilage, and into the anterior border of its inferior cornu. The lower portion of the muscle, the fibres of which are nearly horizontal, and are inserted into the inferior cornu, is usually distinct from the rest. Some of the superficial fibres are almost always continuous with the inferior constrictor of the pharynx. The inner borders of the muscles of the two sides are separated in the middle line by a triangular interval, broader above than below, and occupied by the crico-thyroid membrane.

Fig. 639.

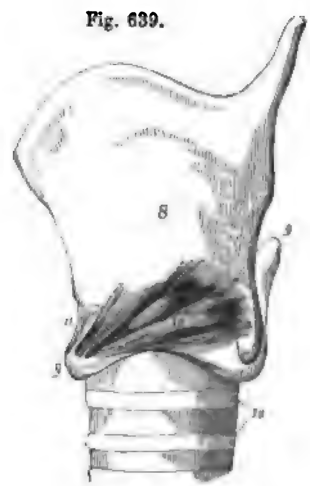


Fig. 639.—Lateral View of the Cartilages of the Larynx with the Crico-Thyroid Muscle (after Willis).

8, thyroid cartilage; 9, cricoid; 10, crico-thyroid muscle; 11, crico-thyroid ligament or membrane; 12, upper rings of the trachea.

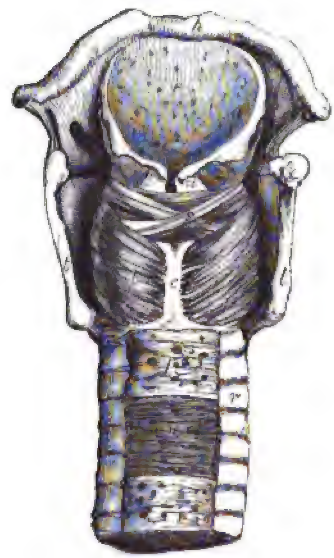
The *posterior crico-arytenoid muscle*, situated behind the larynx, beneath the mucous membrane of the pharynx, arises from the broad depression on the corresponding half of the posterior surface of the cricoid cartilage. From this broad origin its fibres converge upwards and outwards to be inserted into the outer angle of the base of the arytenoid cartilage, behind the attachment of the lateral crico-arytenoid muscle. The upper fibres are short

and almost horizontal; the middle are the longest, and run obliquely; whilst the lower or external fibres are nearly vertical.

Fig. 640.—View of the Larynx and Part of the Trachea from behind, with the Muscles dissected.

h, the body of the hyoid bone; *e*, epiglottis; *t*, the posterior borders of the thyroid cartilage; *c*, the median ridge of the cricoid; *a*, upper part of the arytenoid; *s*, placed on one of the oblique fasciculi of the arytenoid muscle; *b*, left posterior crico-arytenoid muscle; *r*, ends of the incomplete cartilaginous rings of the trachea; *l*, fibrous membrane crossing the back of the trachea; *n*, muscular fibres exposed in a part.

Fig. 640.



In connection with the posterior crico-arytenoid muscle, may be mentioned an occasional small slip in contact with its lower border, viz., the *kerato-cricoid* muscle of Merkel. It is a short and slender bundle, arising from the cricoid cartilage near its lower border, a little behind the inferior cornu of the thyroid cartilage, and passing obliquely outwards and upwards to be inserted into that process. It usually exists on only one side. Turner found it in seven out of thirty-two bodies. It is not known to be of any physiological significance. (Merkel, Anat. und Phys. des Menschl. Stimm-und-Sprāch-organs, Leipzig, 1857; Turner in Month. Med. Journal, Feb. 1860.)

The *lateral crico-arytenoid* muscle, smaller than the posterior, and of an oblong form, is in a great measure hidden by the ala of the thyroid cartilage. It arises from the upper border of the side of the cricoid cartilage, its

Fig. 641.—Diagrammatic View from above of the Dissected Larynx (after Willis).

1, aperture of the glottis; 2, arytenoid cartilages; 3, vocal cords; 4, posterior crico-arytenoid muscles; 5, right lateral crico-arytenoid muscle, that of the left side being removed; 6, arytenoid muscle; 7, thyro-arytenoid muscle of the left side, that of the right side being removed; 8, upper border of the thyroid cartilage; 9, back of the cricoid cartilage; 13, posterior crico-arytenoid ligament.

Fig. 641.

origin extending as far back as the articular surface for the arytenoid cartilage. Its fibres passing obliquely backwards and upwards, and the anterior or upper ones being the longest, are attached to the external process or outer side of the base of the arytenoid cartilage and to the adjacent part of its anterior surface, in front of the insertion of the posterior crico-arytenoid muscle.

This muscle lies in the interval between the ala of the thyroid cartilage

and the interior of the larynx, being lined within by the mucous membrane of the larynx. Its anterior part is covered by the upper part of the crico-thyroid muscle. The upper part is in close contact and indeed is sometimes blended with the thyro-arytenoid muscle.

The *thyro-arytenoid* is a broad flat muscle situated above the lateral crico-arytenoid. It is thick below and in front, and becomes thinner above and behind. It consists of several muscular fasciculi, which arise in front from the internal surface of the thyroid cartilage, adjacent to the lower two-thirds of the angle formed by the junction of the two alæ. They extend almost horizontally backwards and outwards to reach the base of the arytenoid cartilage. The *lower portion* of the muscle, which forms a thick fasciculus, receives a few additional fibres from the posterior surface of the crico-thyroid membrane, and is inserted into the anterior projection on the base of the arytenoid cartilage and to the adjacent part of the surface close to the insertion of the lateral crico-arytenoid muscle. The *thinner portion* of the thyro-arytenoid muscle is inserted higher up on the anterior surface and outer border of the arytenoid cartilage. The lower portion of the muscle assists in the formation, or at least contributes to the support, of the true vocal cord, lying parallel with the rima glottidis, immediately on the outer side of the inferior thyro-arytenoid ligament, with which it is intimately connected, and into the outer surface of which some of its fibres are inserted. The upper thin portion, external to the lower, lies upon the laryngeal pouch and ventricle, close beneath the mucous membrane. The entire muscle may be dissected indeed from the interior of the larynx by raising the mucous membrane of the sinus and vocal cord. Fibres from this muscle pass round the border of the arytenoid cartilage, and become continuous with some of the oblique fibres of the arytenoid muscle, to be presently described.

Fig. 642.

Fig. 642.—View of the Interior of the Left Half of the Larynx (after Hilton).

a, left arytenoid cartilage; *c*, *c*, divided surfaces of the cricoid cartilage; *t*, thyroid cartilage; *e*, epiglottis; *v*, left ventricle of the larynx; *r*, left inferior or true vocal cord; *s*, placed on the inner wall of the laryngeal pouch; *b*, aryteno-epiglottidean muscle; *f*, interior of the trachea.

Santorini described three thyro-arytenoid muscles, an *inferior* and *middle*, which are constant, and a superior, which is sometimes present. The fibres of the superior muscle, when present, arise nearest to the notch of the thyroid cartilage, and are

attached to the upper part of the arytenoid cartilage. This is named by Sœmmerring the *small* thyro-arytenoid, whilst the two other portions of the muscle constitute the *great* thyro-arytenoid of that author.

Arytenoid and aryteno-epiglottidean muscles.—When the mucous membrane is removed from the back of the arytenoid cartilages, a thick band of transverse fibres constituting the arytenoid muscle is laid bare, and on the surface of this are seen two slender decussating oblique bundles, formerly described as portions of the arytenoid muscle (arytænoideus obliquus), but now more generally considered as parts of the aryteno-epiglottidean muscles, with which they are more closely associated both in the disposition of their fibres and in their action. The *arytenoid* muscle passes straight across, and its fibres are attached to the whole extent of the concave surface on the back of each arytenoid cartilage. The *aryteno-epiglottidean* muscles arising near the inferior and outer angles of the arytenoid cartilages, decussate one with the other, and their fibres are partly attached to the upper and outer part of the opposite cartilage, partly pass forwards in the aryteno-epiglottidean fold, and partly join the fibres of the thyro-arytenoid muscle.

A few fibres associated with the anterior and upper part of the thyro-arytenoid muscle have been described as constituting a *thyro-epiglottidean* muscle.

Fig. 643.

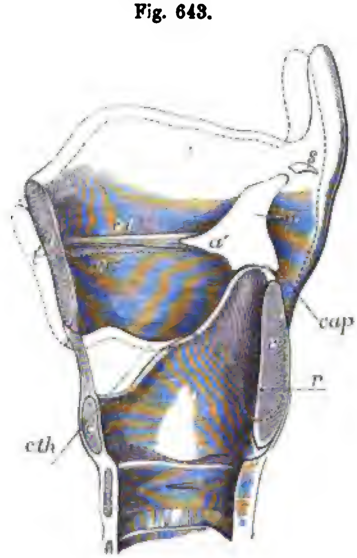


Fig. 643.—Outline of the Right Half of the Cartilages of the Larynx as seen from the Inside, with the Thyro-Arytenoid Ligament, to illustrate the Action of the Crico-Thyroid Muscle.

t, cut surface of the thyroid cartilage in the middle anteriorly; *c*, *c*, the same of the cricoid cartilage before and behind; *a*, the inner surface of the right arytenoid cartilage; *a'*, its anterior process; *s*, the right cartilage of Santorini; *cv*, the thyro-arytenoid ligament; the position of the lower cornu of the thyroid cartilage on the outside of the cricoid is indicated by a dotted outline, and *r* indicates the point or axis of rotation of the one cartilage on the other; *cth*, indicates a line in the principal direction of action of the crico-thyroid muscle; *cap*, the same of the posterior crico-arytenoid muscle; the dotted line, of which *t'* indicates a part, represents the position into which the thyroid cartilage is moved by the action of the crico-thyroid muscle; if the arytenoid cartilages are fixed by muscles acting in the direction of *cap*, the vocal ligaments will be elongated and rendered tense, by contraction of the crico-thyroid muscles, as indicated by *cv'*.

Actions of the intrinsic muscles of the larynx.—The *crico-thyroid* muscles produce the rotation forwards and downwards of the thyroid cartilage on the cricoid, which is permitted by the crico-thyroid articulations. In this movement the arytenoid cartilages, being attached to the cricoid cartilage at a level considerably above the axis of rotation, have their distance from the fore part of the thyroid cartilage increased, and therefore, the crico-thyroid muscles increase the tension of the vocal cords. The *thyro-arytenoid* muscles are, in their lower parts, the opponents of the crico-thyroid, raising the fore part of the thyroid cartilage and decreasing the tension of the vocal

cords; the upper parts of these muscles, being attached higher up on the arytenoid cartilages, depress them.

The *lateral crico-arytenoid* muscles, by pulling forwards the outer angles of the arytenoid cartilages, approximate the vocal cords to the middle line. The *posterior crico-arytenoid* muscles pull backwards the outer angles of the arytenoid cartilages, and thus draw asunder the posterior extremities of the vocal cords, and dilate the glottis to its greatest extent; they are likewise the elevators of the arytenoid cartilages, being inserted above the articulation.

The *arytenoid* muscle draws the arytenoid cartilages together, and from the structure of the crico-arytenoid joints, this approximation when complete is necessarily accompanied with depression. The *aryteno-epiglottidean* muscles at once depress and approximate the arytenoid cartilages, which they include in their embrace, and draw down the epiglottis, so as to contract the whole superior aperture of the larynx.

With the aid of the laryngoscope it may be seen that in ordinary breathing the rima glottidis is widely open, and that in vocalization the vocal cords come closely together; which is effected principally, no doubt, by the action of the lateral crico-arytenoid muscles, assisted by the arytenoid and perhaps by the thyro-arytenoid, and accompanied with a varying amount of contraction of the crico-thyroid muscles. The regulation of the tension of the vocal cords and of the width of the aperture of the glottis, in the production of high and low pitched notes, is probably accomplished by the crico-thyroid and thyro-arytenoid muscles. The movement of the thyroid on the cricoid cartilage, effected by these muscles during the passage of the voice from one extreme of the scale to the other, may be detected by placing the tip of a finger over the crico-thyroid ligament. The arytenoid and aryteno-epiglottidean muscles come into action in spasmodic closure of the upper aperture of the larynx; the complete descent of the epiglottis, however, can only take place when the tongue is retracted as in the act of swallowing.

The manner in which the larynx is affected by the extrinsic muscles, in the acts of deglutition and vocalization, has been mentioned at pages 191 and 193.

It is remarked by Henle that, with the exception of the crico-thyroid and posterior crico-arytenoid, the muscles of the larynx, namely, those "which lie in the space enclosed by the laminæ of the thyroid cartilage, and above the cricoid, the fibres of which are substantially horizontal, may be regarded in their totality as a kind of sphincter. Such a sphincter is found in its simple form embracing the entrance of the larynx in reptiles; and the complication which it attains in the higher vertebrates arises, like the complication of the muscles generally, from the fibres finding various points of attachment in their course, by which means they are broken up and divided."

The *mucous membrane and glands of the larynx.*—The laryngeal mucous membrane is thin and of a pale pink colour. In some situations it adheres intimately to the subjacent parts, especially on the epiglottis, and still more in passing over the true vocal cords, on which it is extremely thin and most closely adherent. About the upper part of the larynx, above the glottis, it is extremely sensitive. In or near the aryteno-epiglottidean folds it covers a quantity of loose areolar tissue, which is liable in disease to infiltration, constituting œdema of the glottis. Like the mucous membrane in the rest of the air passages, that of the larynx is covered in the greater part of its extent with a columnar ciliated epithelium, by the vibratory action of which the mucus is urged upwards. The cilia are found higher up in front than on each side and behind, reaching in the former direction as high as the widest portion of the epiglottis, and in the other directions to a line or two above the border of the superior vocal cords: above these points the epithelium loses its cilia, and gradually assumes a squamous form, like that of the pharynx and mouth. Upon the vocal cords also the epithelium is squamous, although both above and below them it is ciliated.

Glands.—The lining membrane of the larynx is provided with numerous *glands*, which secrete an abundant mucus; and the orifices of which may

be seen almost everywhere, excepting upon and near the true vocal cords. They abound particularly upon the epiglottis, in the substance of which are found upwards of fifty small compound glands, some of them perforating the cartilage. Between the anterior surface of the epiglottis, the hyoid bone, and the root of the tongue, is a mass of yellowish fat, erroneously named the epiglottidean gland, in or upon which some real glands may exist. Another collection of glands, named *arytenoid*, is placed within the fold of mucous membrane in front of each arytenoid cartilage, from which a series may be traced forwards, along the corresponding superior vocal cord. The glands of the laryngeal pouches have already been described.

Vessels and Nerves of the Larynx.

The *arteries* of the larynx are derived from the superior thyroid (p. 343), a branch of the external carotid, and from the inferior thyroid (p. 371), a branch of the subclavian. The *veins* join the superior, middle and inferior thyroid veins. The *lymphatics* are numerous, and pass through the cervical glands. The *nerves* are supplied from the superior laryngeal and inferior or recurrent laryngeal branches of the pneumogastric nerves, joined by branches of the sympathetic. The superior laryngeal nerves supply the mucous membrane, and also the crico-thyroid muscles, and in part the arytenoid muscle. The inferior laryngeal nerves supply, in part, the arytenoid muscle, and all the other muscles, excepting the crico-thyroid.

The superior and inferior laryngeal nerves of each side communicate with each other in two places, viz., at the back of the larynx, beneath the pharyngeal mucous membrane, and on the side of the larynx, under the ala of the thyroid cartilage (p. 622).

DEVELOPMENT AND GROWTH OF THE LARYNX.

Development.—The rudimentary larynx consists, according to Valentin, of two slight enlargements having a fissure between them, and embracing the entrance from the pharynx into the trachea. According to Reichert, the rudiments of the arytenoid cartilages are the first to appear. Rathke, however, states that all the true cartilages are formed at the same time, and are recognisable together as the larynx enlarges, the epiglottis only appearing later. In the human embryo, Fleischmann could not detect the cartilages at the seventh week, though the larynx was half a line in length, but at the eighth week there were visible the thyroid and cricoid cartilages, consisting at that period of two lateral halves, which are afterwards united together in the sixth month. Kölliker, however, states that Fleischmann had been deceived by the presence of a deep groove, and that by making transverse sections he ascertained that those cartilages are single from the first.

Growth.—During childhood the growth of the larynx is very slow. Richerand found that there was scarcely any difference between the dimensions of this organ in a child of three and in one of twelve years of age. Up to the age of puberty the larynx is similar in the male and female, the chief characteristics at that period being the small size and comparative slightness of the organ, and the smooth rounded form of the thyroid cartilage in front. In the female these conditions are permanent, excepting that a slight increase in size takes place. In the male, on the contrary, at the time of puberty, remarkable changes rapidly occur, and the larynx becomes more prominent and more perceptible at the upper part of the neck. Its cartilages become larger, thicker, and stronger, and the alæ of the thyroid cartilage project forwards in front so as to form at their union with one another, with an acute angle, the prominent ridge of the *pomum Adami.* At the same time the median notch on its upper border is considerably deepened. In consequence of these changes in the thyroid cartilage, the distance between its angle in front and the arytenoid cartilages behind becomes greater, and the chordæ vocales are necessarily lengthened. Hence the dimensions of the glottis, which, at the time of puberty, are increased by about one-third only in the female, are nearly doubled in the male, and the adult male larynx becomes altogether one-third larger than that of the female.

Towards the middle of life the cartilages of the larynx first show a tendency to

ossification; this commences first in the thyroid cartilage, then appears in the cricoid, and lastly in the arytenoid cartilages. In the thyroid cartilage the ossification usually begins at the cornua and posterior borders; it then gradually extends along the whole inferior border, and subsequently spreads upwards through the cartilage. The cricoid cartilage first becomes ossified at its upper border upon each side, near the two posterior articular eminences, and the ossification invades the lateral parts of the cartilage before encroaching on it either in front or behind. The arytenoid cartilages become ossified from below upwards.

Ductless glands on the Larynx and Trachea.

1. The thyroid body.

The *thyroid body* or *gland* is a soft reddish and highly vascular organ, situated in the lower part of the neck, embracing the front and sides of the upper part of the trachea, and reaching up to the sides of the larynx. It belongs, like the spleen, to the series of structures known as ductless glands; and although its precise function is unascertained, there is reason to believe that it is in some way connected with the elaboration of the blood.

The thyroid body is of an irregular, semilunar form, consisting of two *lateral lobes*, united together towards their lower ends by a transverse portion named the *isthmus*. Viewed as a whole, it is convex on the sides and in front, forming a rounded projection upon the trachea and larynx. It is covered by the sterno-hyoid, sterno-thyroid, and omo-hyoid muscles, and behind them it comes into contact with the sheath of the great vessels of the neck. Its deep surface is concave where it rests against the trachea and larynx. It usually extends so far back as to touch the lower portion of the pharynx, and on the left side the œsophagus also.

Fig. 644.

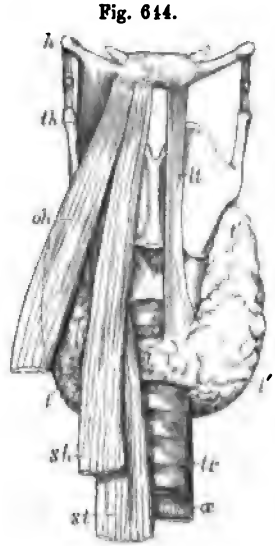


Fig. 644.—Sketch showing the Form and Position of the Thyroid Body. ½

The larynx and surrounding parts are viewed from before; on the right side the muscles covering the thyroid body are retained, on the left side they are removed: *h*, hyoid bone; *th*, right thyro-hyoid muscle; *oh*, omo-hyoid; *sh*, sterno-hyoid; *st*, sterno-thyroid; *c*, on the crico-thyroid membrane above the cricoid cartilage, points by a dotted line to the right crico-thyroid muscle; *tr*, the trachea; *œ*, the œsophagus appearing behind and slightly to the left of the trachea; *t*, the right lobe of the thyroid body partially seen between the muscles; *t'*, the left lobe entirely exposed; *i*, the isthmus; *lt*, the fibrous or muscular band termed levator thyroideæ, which is occasionally found in the middle line or to the left side, and which existed in the case from which the figure was taken.

Each *lateral lobe* measures usually two inches or upwards in length, an inch and a quarter in breadth, and three-quarters of an inch in thickness at its largest part, which is below its middle: the right lobe is usually a few lines longer and wider than the left. The general direction of each lobe is, from below, obliquely upwards and backwards, reaching from the fifth or sixth ring of the trachea to the posterior border of the thyroid cartilage, of which it covers the inferior cornu and adjoining part of the ala. The upper end of the lobe, which is thinner,

and sometimes called the *cornu*, is usually connected to the side of the thyroid and cricoid cartilages by areolar tissue.

The *transverse* part, or *isthmus*, which connects the two lateral lobes together a little above their lower ends, measures nearly half an inch in breadth, and from a quarter to three-quarters of an inch in depth; it commonly lies across the third and fourth rings of the trachea, but is very inconstant in size, shape, and position, so that the portion of trachea which is covered by it is subject to corresponding variation. From the upper part of the isthmus, or from the adjacent portion of either lobe, but most frequently the left, a conical portion of the thyroid body, named, from its shape and position, the *pyramid*, or *middle lobe*, often proceeds upwards to the middle of the hyoid bone, to which its apex is attached by loose fibrous tissue. Commonly this process lies somewhat to the left; occasionally it is thicker above than below, or is completely detached, or is split into two parts: sometimes it appears to consist of fibrous tissue only. In many cases, muscular fasciculi, most frequently derived from the thyro-hyoid muscle, but occasionally independent, descend from the hyoid bone to the thyroid gland or its pyramidal process. They are known as the *levator glandulæ thyroideæ*. It sometimes, though rarely, happens that the isthmus is altogether wanting, the lateral lobes being then connected by areolar or fibrous tissue only.

The *weight* of the thyroid body varies ordinarily from one to two ounces. It is always larger in the female than in the male, and appears in many of the former to undergo a periodical increase about the time of menstruation. The thyroid body, moreover, is subject to much variation of size, and is, occasionally, the seat of enormous enlargement, constituting the disease called goître. The *colour* of the thyroid body is usually of a dusky brownish red, but sometimes it presents a yellowish hue.

Fig. 645.

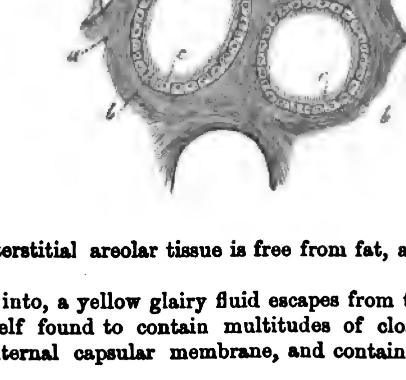


Fig. 645.—MAGNIFIED VIEW OF SEVERAL VESICLES FROM THE THYROID GLAND OF A CHILD (from Kölliker). $\frac{250}{1}$

a, connective tissue between the vesicles; *b*, capsule of the vesicles; *c*, their epithelial lining.

Structure.—The texture of this organ is firm, and to the naked eye appears coarsely granular. It is invested with a thin transparent layer of dense areolar tissue, which connects it with the adjacent parts, surrounds and supports the vessels as they enter it, and imperfectly separates its substance into small masses of irregular form and size. The interstitial areolar tissue is free from fat, and contains elastic fibres.

When the thyroid body is cut into, a yellow glairy fluid escapes from the divided substance, which is itself found to contain multitudes of closed vesicles, composed of a simple external capsular membrane, and containing

a yellow fluid, with corpuscles resembling cell-nuclei and sometimes nucleated cells floating in it. These vesicles are surrounded by capillary vessels, and are held together in groups or imperfect lobules by areolar tissue. Their size varies from $\frac{1}{850}$th of an inch to that of a millet-seed, so as to be visible to the naked eye,—the size varying, however, in different individuals, more than in the same thyroid body. The *vesicles* are spherical, oblong, or flattened, and are perfectly distinct from each other; the *corpuscles* within them are in the fœtus and young subject disposed in close apposition and like a single epithelial layer on the inner side of the vesicles, but for the most part detach themselves in the progress of growth. The fluid coagulates by the action of heat or of alcohol, preserving, however, its transparency. According to recent analyses, the substance of the thyroid body consists principally of albumen with traces of gelatine, stearine, oleine, and extractive matter, besides alkaline and earthy salts and water. The salts are chloride of sodium, a little alkaline sulphate, phosphates of potash, lime and magnesia, with some oxide of iron.

Fig. 646.

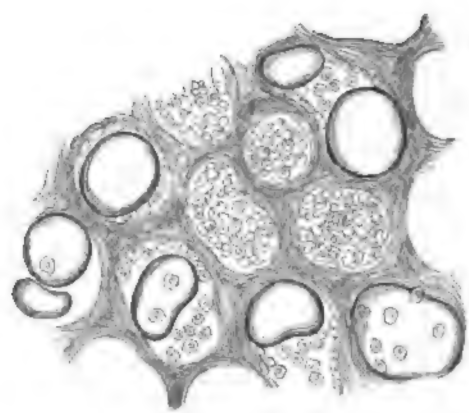


Fig. 646.—Vesicles of the Thyroid Gland enlarged and containing Colloid Matter (from Kölliker). $\frac{50}{1}$

One of the most frequent pathological changes to which the thyroid body is subject consists in the accumulation within its vesicles of colloid substance: this may occur without giving rise to very great enlargement of these vesicles, but in certain forms of goître it distends them to an enormous degree.

Vessels.—The *arteries* of the thyroid body (pp. 346 and 371) are the superior and inferior thyroids of each side, to which is sometimes added a fifth vessel named the *lowest* thyroid of Neubauer and Erdmann (p. 340). The arteries are remarkable for their large relative size, and for their frequent and large anastomoses; they terminate in a capillary network, upon the outside of the closed vesicles. The *veins*, which are equally large, ultimately form plexuses on the surface, from which a superior, middle, and inferior thyroid vein (pp. 453 and 460) are formed on each side. The superior and middle thyroid veins open into the internal jugular; the inferior veins emanate from a plexus formed in front of the trachea, and open on the right side into the superior cava, and on the left into the brachio-cephalic vein. The *lymphatics* of the thyroid body are extremely numerous and large, and are supposed to convey into the blood the products formed within the organ.

Nerves.—The *nerves* are derived from the pneumogastric, and from the middle and inferior cervical ganglia of the sympathetic.

Development.—Remak states that the thyroid body is developed from the anterior wall of the pharynx. In a human embryo at the third month, Kölliker found the thyroid body consisting of isolated vesicles, with rounded cells in their interior. The multiplication of these vesicles takes place, according to Kölliker, either by constriction and subsequent division of one vesicle into two; or by a process of gemmation. The transverse part of the gland is said to be developed subsequently to the two lateral

lobes. In the fœtus, and during early infancy, this organ is relatively larger than in after life; its proportion to the weight of the body in the new-born infant being that of 1 to 240 or 400, whilst at the end of three weeks it becomes only 1 to 1160, and in the adult 1 to 1800 (Krause). In advanced life the thyroid body becomes indurated, and frequently contains earthy deposit; its vesicles also attain a very large size.

2. THE THYMUS GLAND.

The *thymus gland* or *body* (glandula thymus, corpus thymicum) is a temporary organ which reaches its greatest size at about the end of the second year, after which period it ceases to grow, and is gradually reduced to a mere vestige. Its function, like that of the thyroid body, is unknown, although it is probable that it is in some way connected with the elaboration of the blood in infancy. When examined in its mature state in an infant under two years of age, it appears as a narrow elongated glandular-looking body, situated partly in the thorax, and partly in the lower region of the neck: below, it lies in the anterior mediastinal space, close behind the sternum, and in front of the great vessels and pericardium; above it reaches upwards upon the trachea in the neck. Its colour is greyish, with a pinkish tinge; its consistence is soft and pulpy, and its surface appears distinctly lobulated. It consists of *two lateral parts*, or *lobes*, which touch each other along the middle line, and are nearly symmetrical in form, though generally unequal in size, sometimes the left, and at other times the right lobe being the larger of the two. An *intermediate lobe* often exists between the two lateral ones, and occasionally the whole body forms a single mass. The forms of the smaller lobules also differ on the two sides.

Fig. 647.

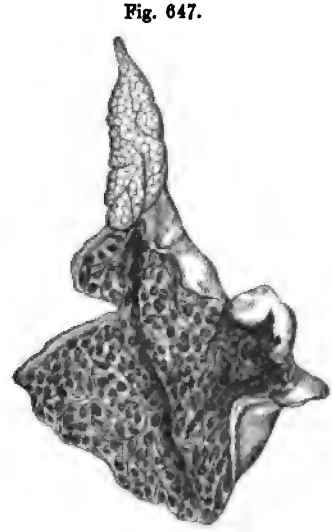


Fig. 647.—One Lobe of the Human Thymus Gland (from Kölliker).

The lower part presents a large cavity which has been opened, and within it are seen numerous apertures leading into the smaller lobes.

Each lateral lobe is of an elongated triangular form, its base being directed downwards. The *summit*, or upper extremity, usually mounts up into the neck, reaching as high as to the lower border of the thyroid body. The *base* rests on the upper part of the pericardium, to which it is connected by areolar tissue. The *anterior* surface, slightly convex, is covered by the first and the upper part of the second piece of the sternum, reaching, in the infant at birth, as low down as the level of the fourth costal cartilage. It is attached to the sternum by loose areolar tissue, but opposite the upper part of that bone is separated from it by the origins of the sterno-hyoid and sterno-thyroid muscles, which also cover it in the neck. The *posterior* surface, somewhat concave, rests, in the thorax, upon part of the pericardium, upon the front of the aortic arch and the large arteries arising from it, and also on

the left innominate vein, some areolar tissue being interposed between it and these parts. In the neck, it lies upon the front and corresponding side of the trachea. Its *external border* is in contact with the corresponding layer of the mediastinal pleura, near the internal mammary artery, and higher up (in the neck), with the carotid artery, or its sheath. The *internal* border is in close contact with that of the opposite lateral lobe. The dimensions of the thymus vary according to its stage of development. At birth it measures above two inches in length, an inch and a half in width at its lower part, and about three or four lines in thickness. Its weight at that period is about half an ounce. Its specific gravity, which is at first about 1·050, diminishes as the gland continues to waste.

Chemical Composition.—The substance and fluid of the thymus contain nearly eighty per cent. of water. Its solid animal constituents are composed essentially of albumen and fibrin in large quantities, mixed with gelatine and other animal matter. The salts are principally alkaline and earthy phosphates, with chloride of potassium.

Structure.—The lateral halves or lobes of the thymus gland are each surrounded by a proper investment of thin areolar tissue, which encloses in a common envelope the smaller masses composing it. This tissue being removed, the substance of the gland is found to consist of numerous compressed lobules, the most of them from two to five lines in diameter, connected by a more delicate intervening areolar tissue. These primary lobules, as they may be called, are each made up externally of smaller or secondary lobules, of a compressed pyriform shape, placed close together with their bases outwardly, and are arranged round an elongated *central stem* (reservoir of the thymus, Cooper), running through each lateral half of the gland, and more or less spirally twisted.

On making a section of the thymus, there is obtained a milky substance consisting of fluid rich in nuclei and small nucleated cells. The walls both of the lobules and the larger stems are limited by a fine homogeneous membrane (Simon); the substance in the interior of this appears at first sight to be entirely composed of corpuscles of the kind just mentioned, varying in diameter from $\frac{1}{2500}$th to $\frac{1}{5000}$th of an inch, and having the appearance of free nuclei; but, on closer examination, according to Kölliker and His, seen to be mostly contained within delicate cells. The substance contained within the limiting membrane is not, however, a mere fluid with corpuscles, but possesses a delicate reticulum of connective tissue, and, as was first pointed out by Kölliker, likewise capillary blood vessels, resembling in this respect the substance which occupies the interior of Peyer's glands.

According to Astley Cooper the central stem of the thymus presents a continuous cavity, the ramifications of which pass into both primary and secondary lobules. The existence of a central cavity has been since doubted by some and affirmed by others; the difficulty, however, may now be regarded as cleared up, since the discovery of connective tissue and blood-vessels within the lobulated structure; for it is admitted that in the centres of the lobules, sub-lobules and central stem, the capillaries and reticulum of connective tissue are deficient and the corpuscles most abundant, while on the other hand it is equally certain that there is no cavity bounded by epithelial lining. Considered in relation to development, Cooper's view is correct; for it has been shown by Simon that the primitive form of the thymus gland is a linear tube, from which, as it grows, lateral branched diverticula subsequently bud out, but that in the mature thymus this tube becomes obscure.

He is of opinion that the central cavity described and figured by Cooper is preternaturally enlarged, owing to over-distension; but that, neverthless, all the parts of each lateral mass of the thymus are connected with a single

Fig. 648.

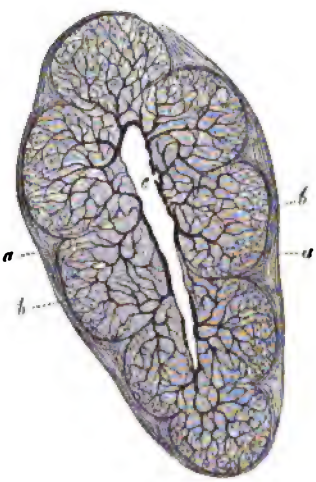


Fig. 648.—Transverse Section of a Lobule of an Injected Infantile Thymus Gland (from Kölliker). $\frac{30}{1}$

a, capsule of connective tissue surrounding the lobule; *b*, membrane of the glandular vesicles; *c*, cavity of the lobule, from which the larger bloodvessels are seen to extend towards and ramify in the spheroidal masses of the lobule.

common cavity. (Astley Cooper, Anatomy of the Thymus Gland, Lond., 1832; Simon, Physiological Essay on the Thymus Gland, Lond., 1845; His, on the Lymphatics of the Thymus, in Zeitsch. f. wissensch. Zoologie, X. and XI.; Kölliker and Henle in their respective Handbooks.)

Vessels.—The *arteries* of the thymus are derived from various sources, viz., from the internal mammary arteries, the inferior and superior thyroid, the subclavian and carotid arteries. They terminate in capillary vessels, which form a vascular envelope around and within each vesicle.

The *veins* pursue a different course from the arteries, and, for the most part, open into the left innominate vein.

The *lymphatics* are large. According to the observations of His on the calf, the larger blood-vessels passing to the central canal are each accompanied by two or more lymphatic stems. He finds that these arise from an interlobular plexus of lymphatic spaces destitute of walls, and that this plexus receives its roots from the interior of the lobules; and he advances the opinion that they communicate directly with the central spaces of the lobules; he has not, however, actually observed such a connection.

The *nerves* are very minute. Haller thought they were partly derived from the phrenic nerves, but according to Cooper, no filaments from these nerves go into the gland, though they reach the investing capsule, as does also a branch from the descendens noni. Small filaments, derived from the pneumogastric and sympathetic nerves, descend on the thyroid body, to the upper part of the thymus. Sympathetic nerves also reach the gland along its various arteries.

Development.—The early development of the thymus has been carefully studied by Simon, whose researches were chiefly conducted in the embryos of swine and oxen. In embryos about half an inch in length, it may be seen with the aid of a high magnifying power; and in those of one and a half inch, with the aid of a simple lens. When first distinguishable, it consists of a simple tube closed in all directions, lying along the carotid vessels. The contents of this tube are granular, but do not show regular corpuscles; its walls are delicate and homogeneous. The tube has no connection with the respiratory mucous membrane, as was supposed by Arnold; and so soon as it is discoverable, it is found to be perfectly distinct from the thyroid body. At intervals along the sides of this tube small vesicles bud out, so as to form lateral diverticula, which contain nucleated corpuscles, and which go on subsequently branching out in groups of two or four,—the formation of the permanent vesicles being merely the last repetition of this process. In the human fœtus at the seventh week, Kölliker has seen the thymus lobate at its lower end, and single above; at about the ninth week the thymus consists of two minute elongated parallel parts,

lying chiefly on the upper part of the pericardium, and presenting under the microscope a distinct tubulo-vesicular structure filled with polygonal cells; at the twelfth week the thymus is broad, and its surface is entirely covered with lobules; it then increases rapidly until birth, but not with uniform rapidity, for it grows especially during the seventh, eighth, and ninth months of intra-uterine existence.

After birth, the thymus, as already stated, continues to grow to near the end of the second year. According to the observations of Haugstedt and Simon upon the weight of this organ in young animals, it appears for a short time after birth to increase not merely absolutely, but even faster than the rest of the system, and during the next period only to keep pace with the increase of the body. After the second year it ceases to grow, and becomes gradually converted by the eighth or twelfth year into a fatty mass. In this condition the corpuscles of the thymus disappear, forming, according to Simon's opinion, the nuclei of cells which become developed into the cells of adipose tissue. At puberty the thymus is generally reduced to a mere vestige which has entirely lost its original structure, and consists of brownish tissue occupying the upper part of the anterior mediastinum. Occasionally it is still found in good condition at the twentieth year; but generally only traces of it remain at that time, and these are rarely discoverable beyond the twenty-fifth or thirtieth year.

The thymus gland presents no difference in the two sexes. It exists, according to Simon, in all animals breathing by lungs, and is persistent in those which hybernate, though only as a mass of fat.

THE URINARY ORGANS.

The urinary organs consist of the *kidneys*, the glandular organs by which the urine is secreted, and of the *ureters*, *bladder*, and *urethra*, which are the organs of its excretion and evacuation. As being locally connected, the *supra-renal* capsules are usually described along with these organs, though they have no relation, as far as is known, to the secretion of urine.

THE KIDNEYS.

The *kidneys*, two in number, are deeply seated in the lumbar region, lying one on each side of the vertebral column, at the back part of the abdominal cavity, and behind the peritoneum. They are situated on a level with the last dorsal and the two or three upper lumbar vertebræ, the right kidney, however, being placed a little lower down than the left, probably in consequence of the vicinity of the large right lobe of the liver. They are maintained in this position by their vessels, and also by a quantity of surrounding loose areolar tissue, which usually contains much dense fat (tunica adiposa). The *size* of the kidneys varies in different instances. Ordinarily, they measure about four inches in length, two and a half inches in breadth, and an inch and a quarter or more in thickness. The left kidney is usually of a longer and thinner shape, whilst the right is shorter and wider.

Weight.—The *average* weight of the kidney is usually stated to be about 4½ oz. in the male, and somewhat less in the female. According to Clendinning, the two kidneys of the male weigh on an average 9½ oz., and those of the female 9 oz. The estimate of Rayer is 4½ oz. for each organ in the male, and 3⅞ oz. in the other sex. Reid's observations (made on sixty-five males and twenty-eight females, between the ages of twenty-five and fifty-five) would indicate a higher average weight, viz., rather more than 5½ oz. in the former, and not quite 5 oz. in the latter,—the difference between the two sexes being therefore upwards of half an ounce. The *prevalent* weights of the kidney, as deduced from the tables of Reid, are, in the adult male (160 observations) from 4½ oz. to 6 oz., and in the adult female (74 observations) from 4 oz. to 5½ oz. The tables more recently published by Peacock give still higher average results as to the weight of these organs. The two kidneys are seldom of equal

weight, the left being almost always heavier than the right. The difference, according to Rayer, is equal to about one-sixth of an ounce. The actual average difference was found by Reid in ninety-three cases (male and female), to be rather more than one-fourth of an ounce. The *proportionate* weight of the two kidneys to the *body* is about 1 to 240.

The *specific gravity* of the renal substance is, on an average, 1·052.

The surface of the kidney is smooth and has a deep red colour. Its *form* is peculiar: it is compressed before and behind, convex on its outer and concave on its inner border, and somewhat enlarged at its upper and lower ends.

The *anterior* surface, more convex than the posterior, is directed somewhat outwards, and is partially covered at its upper end by the peritoneum, which is separated from it lower down by loose areolar tissue. The duodenum and ascending colon, both destitute of peritoneum behind, are in contact with the anterior surface of the right kidney, and the descending colon with that of the left. The front of the right kidney, moreover, touches the under surface of the liver, and that of the left the lower extremity of the spleen. The *posterior* surface, flatter than the anterior, and imbedded in areolar tissue, rests partly upon the corresponding pillar of the diaphragm, in front of the eleventh and twelfth ribs, partly on the anterior layer of the lumbar fascia, covering the quadratus lumborum muscle; and, lastly, on the psoas muscle. The *external border*, convex in its general outline, is directed outwards and backwards towards the wall of the abdomen. The *internal border*, concave and deeply excavated towards the middle, is directed a little downwards and forwards. It presents in its middle a longitudinal *fissure* bounded by an anterior and posterior lip, and named the *hilus of the kidney*, at which the vessels, the excretory duct, and the nerves enter or pass out. In this hilus, the renal vein lies in front, the artery and its branches next, and the expanded excretory duct or ureter behind and towards the lower part of the hilus. The *upper end* of the kidney, which is larger than the lower, is thick and rounded, and supports the suprarenal capsule, which descends a little way upon its anterior surface. This end of the kidney reaches, on the left side, to about the upper border of the eleventh rib, and, on the right, half a rib's breadth lower. It is moreover directed slightly inwards, so that the upper ends of the two kidneys are nearer to each other than the lower ends, which are smaller and somewhat flattened, diverge slightly from the spine, and reach nearly as low as the crest of the ilium. It may here be remarked that, by placing the larger end of a kidney upwards and its flatter surface backwards, or by noticing the relation of the parts in the hilus, the side of the body to which the organ belongs may be determined.

Varieties.—The kidneys present varieties in form, position, absolute and relative size, and number. Thus, they are sometimes found longer and narrower, and sometimes shorter and more rounded than usual. Occasionally one kidney is very small, whilst the other is proportionately enlarged. The kidneys may, one or both, be situated lower down than usual, even in the pelvis.

Instances are now and then met with in which only one kidney is present, the single organ being sometimes, though not always, formed by the apparent junction of the two kidneys across the front of the great blood-vessels and vertebral column. The united organ has usually the form of a crescent, the concavity of which is directed upwards,—hence the appellation of the *horse-shoe* kidney. Sometimes two united kidneys are situated on one or other side of the vertebral column, in the lumbar region, or, but much more rarely, in the cavity of the pelvis. In other very rare cases, three distinct

glandular masses have been found, the supernumerary organ being placed either in front or on one side of the vertebral column, or in the pelvic cavity.

Structure.—The kidney is surrounded by a proper fibrous coat, which forms a thin, smooth, but firm investment, closely covering the organ. It consists of dense fibro-areolar tissue, together with numerous fine elastic fibres, and can easily be torn off from the substance of the gland, to which it adheres by minute processes of connective tissue and vessels.

On splitting open the kidney by a longitudinal section, from its outer to its inner border, the fissure named the *hilus* is found to extend some distance into the interior of the organ, forming a cavity called the *sinus* of the kidney, into the bottom of which the fibrous coat is prolonged. In such a section also the commencement of the excretory duct and the disposition of the substance of the organ are seen to the greatest advantage.

The *ureter*, or excretory duct of the gland, which is dilated at its upper end as it approaches the hilus, is seen to expand within the sinus into a funnel-shaped cavity, compressed from before backwards, named the *pelvis* of the kidney. Within the sinus, partly concealed by the vessels, the pelvis divides usually into three, or sometimes only two, principal tubes, which subdivide into several smaller tubes named the *calyces* or *infundibula*. These calyces, which vary in number from seven to thirteen or more, form short funnel-shaped tubes, into each of which a *papilla* of the renal substance projects. A single calyx often surrounds two, sometimes even three papillæ, which are in that case united together: hence, the calyces are in general not so numerous as the papillæ. The spaces between the calyces are occupied by a considerable amount of fat, imbedded in which are seen the main branches of the renal vessels.

Fig. 649.

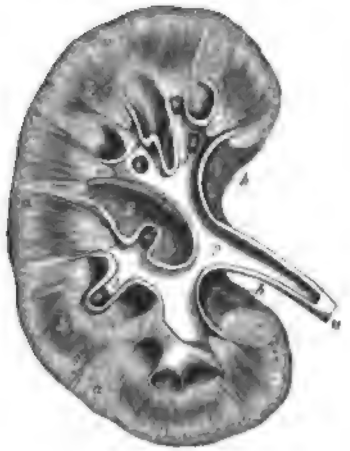


Fig. 649.—Plan of a Longitudinal Section through the Pelvis and Substance of the Right Kidney. ½

a, the cortical substance; *b*, *b*, broad part of two of the pyramids of Malpighi; *c*, *c*, the divisions of the pelvis named calyces, or infundibula, laid open; *c′*, one of these unopened; *d*, summit of the pyramids or papillæ projecting into calyces; *e*, *e*, section of the narrow part of two pyramids near the calyces; *p*, pelvis or enlarged divisions of the ureter within the kidney; *u*, the ureter; *s*, the sinus; *h*, the hilus.

Like the rest of the ureter, the pelvis and greater part of the calyces consist of three coats, viz., a strong external fibro-areolar and elastic tunic, which becomes continuous round the bases of the papillæ with that part of the proper coat of the kidney which is continued into the sinus; secondly, a thin internal mucous coat, which is reflected over the summit of each papilla; and thirdly, between these two, a double layer of muscular fibres, longitudinal and circular. The longitudinal fibres are lost near the base of the calyx, but the circular fibres, according to Henle, form a continuous

circular muscle round the papilla where the wall of the calyx is attached to it.

The *substance* of the kidney consists of two parts, the medullary and cortical, differing in colour, consistence, and structure.

The *internal* or *medullary substance* does not form a continuous structure, but is collected into a series of conical masses called the *pyramids of Malpighi*, the bases of which, directed towards the surface of the kidney, are imbedded in the cortical substance, whilst their apices are turned towards the sinus, and, projecting into the calyces, form the *papillæ* already mentioned. There are generally more than twelve pyramids, but their number is inconstant, varying from eight to eighteen. The medullary portion of the kidney is more dense than the cortical, and is distinctly striated, owing to its consisting of small diverging uriniferous tubes, and to its bloodvessels being arranged in a similar manner. Towards the papillæ the pyramids are of lighter colour than the cortical substance, but at their base they are usually purplish and darker.

The *external* or *cortical* substance is situated immediately within the fibrous capsule, and forms the superficial part of the organ throughout its whole extent to the depth of about two lines, and moreover sends prolongations inwards (septula renum, or columnæ Bertini) between the pyramids. It is of a nearly uniform light crimson brown appearance, and is soft and easily lacerated in directions vertical to the surface. When so lacerated, its torn surface exhibits a columnar appearance, coarser than that of torn medullary substance, and more rough and irregular; the columnar appearance arising from the alternation of groups of straight and convoluted tubules, and the roughness being caused by the convoluted tubules and the interspersion of small round bodies of a deeper colour, the Malpighian corpuscles. The groups of straight tubules in the cortical substance are continued from those of the medullary substance, and are surrounded by the convoluted tubes into which they pass, not only on their sides but likewise at their outer extremities, so that no straight tubules reach the surface of the organ: they are termed *pyramids of Ferrein*. The Malpighian corpuscles are imbedded among the convoluted tubes, and appear disposed in double rows between the pyramids of Ferrein, and likewise more superficially, but nowhere reach quite to the surface.

The pyramidal masses found in the adult kidney indicate the original separation of this gland into lobules in the earlier stages of its growth (fig. 659). Each of these primitive lobules is in fact a pyramid surrounded by a proper investment of cortical substance, and is analogous to one of the lobules of the divided kidneys, seen in many of the lower animals. As the human kidney continues to be developed, the adjacent surfaces of the lobules coalesce and the gland becomes a single mass, and the contiguous parts of the originally separate cortical investments, being blended together, form the partitions between the pyramids already described. Moreover, upon the surface of the kidney even in the adult, after the removal of the fibrous capsule, faintly-marked furrows may be traced on the cortical substance, opposite the intervals in the interior between the several papillæ with their calyces; and not unfrequently instances occur in which a deeper separation of the original lobules by grooves remains apparent in the adult kidney.

Tubuli uriniferi.—On examining the summit of one of the papillæ carefully, especially with the aid of a lens, a number of small orifices may be seen, varying in diameter from $\frac{1}{300}$th to $\frac{1}{200}$th of an inch; they are frequently collected in large numbers at the bottom of a slight depression or

foveola found near the summit of the papilla, but most commonly the surface is pitted over with about a score of minute depressions of this sort. On tracing these minute openings into the substance of the pyramids, they are discovered to be the mouths of small tubes or *ducts*, called the *uriniferous tubes* (tubuli uriniferi), which thus open upon the surface of the several papillæ into the interior of the calyces.

As these tubuli pass up into the pyramidal substance, they bifurcate again and again at very acute angles, their successive branches running close together in straight and slightly diverging lines, and continuing thus to divide and subdivide until they reach the sides and bases of the pyramids, from whence they pass, greatly augmented in number, into the cortical substance, where they enter the pyramids of Ferrein. These straight tubules continued up from the orifices in the papillæ are sometimes called *ducts of Bellini*: they are largest near their orifices, at a short distance from which, within the papillæ, their diameter varies, according to Huschke, from $\frac{1}{430}$th to $\frac{1}{240}$th of an inch. Farther on in the pyramid they become smaller, measuring about $\frac{1}{600}$th of an inch in diameter, and then do not diminish as they continue to bifurcate, but remain nearly of the same uniform average diameter.

The *convoluted tubes*, tubuli contorti, which form the greater part of the cortical substance, and, together with vessels and connecting stroma, the whole of its outermost portion, vary considerably in diameter, but they maintain commonly the same average width as the straight tubes, namely $\frac{1}{600}$th of an inch. The epithelium in the convoluted tubules may be termed cubical; it does not present any marked contrasts in thickness, but in some of the smaller tubules it is clear, while in the majority it is turbid, and with its cells ill-defined.

Besides these tubes, long well known to anatomists, attention has more recently been called by Henle to the presence in the Malpighian pyramids of a number of tubes, which may be roughly estimated as having only a third or a fourth of the diameter of the others, and which, after descending between the larger tubes a variable distance towards the papillæ, then turn abruptly and reascend. The tubes in question have been designated *looped tubes* of Henle. According to this author, the small differ from the large tubes not only in size but in the greater thickness of their walls. By the action of dilute hydrochloric acid the epithelium of the large tubes is destroyed and that of the looped tubes brought into view. The epithelium of the looped tubes, Henle also states, is clear and squamous towards the papillæ, but towards the bases of the pyramids it becomes turbid, like that of the convoluted tubules.

Chrzonszczewsky, while he both figures and describes looped uriniferous tubes, considers that the merit of having discovered them rests with Ferrein, and that those described by Henle as having squamous epithelium are really bloodvessels. Although, however, it is admitted that loops are formed by bloodvessels very similar to the looped tubes of Henle, it must be regarded as certain that loops of the uriniferous tubules are much more numerous than Chrzonszczewsky is willing to admit, and for a knowledge of them as constant and regularly disposed elements of the renal structure science is indebted to Henle.

Imbedded among the convoluted tubules are the Malpighian corpuscles, the structure and connections of which must be taken into consideration, before the disputed course of the uriniferous tubes can be discussed.

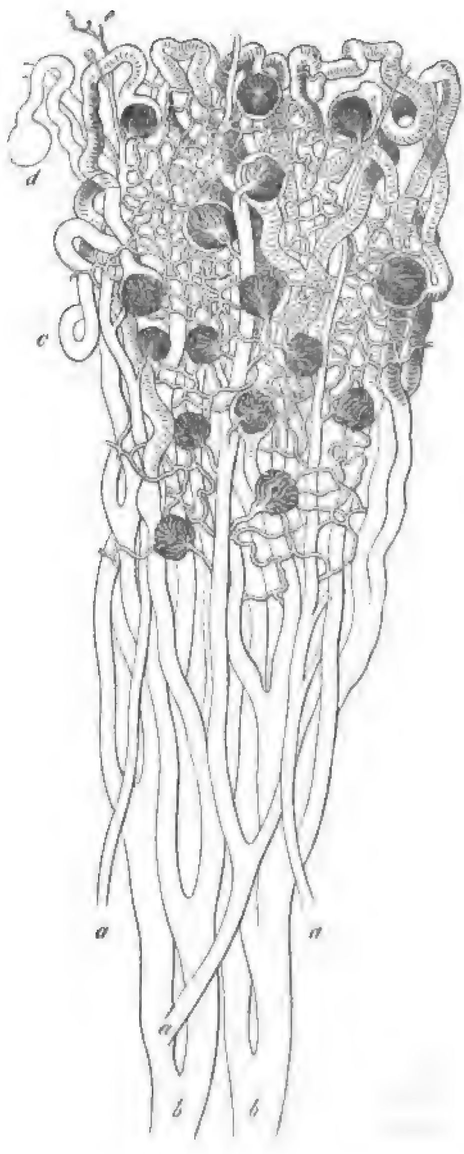
The Malpighian corpuscles are small bodies of a rounded or slightly oblong shape, which have an average diameter of $\frac{1}{120}$th of an inch, but

sometimes of only $\frac{1}{250}$th or $\frac{1}{270}$th of an inch. They consist each of a membranous capsule, containing a tuft of blood-vessels. The vascular tuft or

Fig. 650.—Diagrammatic Representation of a part of the straight and convoluted Uriniferous Tubes with the Glomeruli (from Frey after a drawing by Müller).

b, *b*, two large straight tubes in the medullary substance of the pyramid; *c*, convoluted tubes with several of their terminations in the Malpighian capsules as in *d*; *a*, three arteries passing up the pyramid and dividing into branches to the glomeruli: the efferent vessels are also represented and the network of capillaries between them and the veins.

Fig. 650.



glomerulus is formed by a small *afferent* artery breaking up at once into a number of minute branches, which possess simple nucleated walls, form convoluted loops, and are reunited in a single *efferent* vessel, placed close to the afferent: the further history of the afferent and efferent vessels will be described later. The *capsule*, by which the glomerulus is surrounded, is formed of homogeneous membrane. The glomerulus receives the two vessels at one part; and at another it is continued into a convoluted uriniferous tubule, as was first pointed out by Bowman. Gerlach and others have considered that it may be formed on one side; or may be so placed at the extreme point of a looped tubule, that it appears to be continuous with two tubuli; but it is now generally admitted as the result of filling the tubes both by injections from the ureter and by extravasation from the glomeruli, that although in certain amphibia they may be placed

laterally, in mammals they are always terminal, communicating with one tubule only. The interior of the capsule is lined by a transparent delicate squamous epithelium; but there is still much difference of opinion as to the exact relation of the glomerulus to the epithelium within the capsule. Bowman has described the glomerulus as hanging naked in the interior of the capsule, and presenting thus the greatest possible facility for the filtration of water from its vessels into the tubule: a view which has been supported by Ecker, Henle, and others. Kölliker, on the other hand, has observed epithelium on the free extremity of the glomerulus, looking towards the commencing tubule, while at the sides he can find only a single layer, which he

Fig. 651.

Fig. 652.

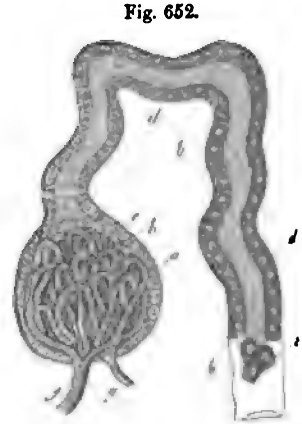


Fig. 651.—Three Malpighian Capsules in connection with the Bloodvessels and Uriniferous Tubes of the Human Kidney (from Kölliker after Bowman).

a, termination of an interlobular artery; *b*, afferent arteries; *c*, a denuded vascular glomerulus; *d*, efferent vessel; *e*, two of the glomeruli enclosed by the Malpighian capsules; *f*, uriniferous tubes connected with them.

Fig. 652.—Semidiagrammatic representation of a Malpighian Body in its relation to the Uriniferous Tube (from Kölliker).

1. *a*, capsule of the Malpighian body continuous with *b*, the membrana propria of the coiled uriniferous tube; *c*, epithelium of the Malpighian body; *d*, epithelium of the uriniferous tube; *e*, detached epithelium; *f*, afferent vessel; *g*, efferent vessel; *h*, convoluted vessels of the glomerulus.

represents as adherent on one side to the glomerulus, and on the other to the capsular wall. Lastly, Isaacs, Moleschott, and Chrzonszczewsky maintain that the glomerulus and the capsule have each a separate coating of epithelium, and they agree in stating that the cells of the layer covering the glomerulus are considerably larger than those lining the capsule: Chrzonszczewsky recommends sections of frozen kidneys as showing very perfectly the two layers *in situ*.

Origin, course, and connections of the uriniferous tubules.—When the tubuli uriniferi are followed in their apparent course, the straight tubes are easily traceable from the Malpighian pyramids into the pyramids of Ferrein, and from these into the tubuli contorti. Thus, after the observations of Bowman had demonstrated the connection of the Malpighian corpuscles with the tubuli contorti, it appeared natural to believe that the tubuli contorti at one extremity commenced in capsules of Malpighian corpuscles, and at the other were continued into straight tubules, which opened at the summits of the papillæ. It appears, however, from the concurrent testimony of recent writers that considerable complexity of arrangement intervenes between the terminations of the straight tubes and the commencements of the tubuli contorti, with which the Malpighian corpuscles are connected.

Fig. 653.

Fig. 653.—Portion of the Uriniferous Tubes, magnified (from Baly).

A, portion of a convoluted tube from the cortical substance; B, epithelial cells from the interior of the tube, magnified 700 diameters.

It may be considered as certain from the researches of Ludwig and Zuwarykin conducted by means of injections, and from those of Schweigger-Seidel by means of isolation of the tubules in small animals, that the tubuli contorti which commence in the Malpighian corpuscles are continued into the looped tubes of Henle, and that these open into the straight tubules or ducts of Bellini, either directly or through the intervention of convoluted tubes of junction of larger size, said by Schweigger-Seidel to be always present. According to Henle the straight tubules turn rather sharply round near the surface of the kidney, and again course inwards; and this appearance, which has been corroborated by other observers, he believes to result from anastomoses of the tubules in arches, two and two. It must be regarded as a question still

Fig. 654.

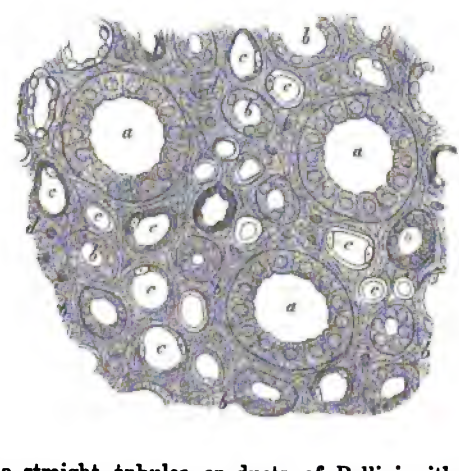


Fig. 654.—Transverse Section of a Renal Papilla (from Kölliker). $\frac{300}{1}$

a, larger tubes or papillary ducts; *b*, smaller tubes of Henle; *c*, bloodvessels, distinguished by their flatter epithelium; *d*, nuclei of the stroma.

open to discussion whether all the smaller tubules which open into these arches belong to the convoluted and looped tubules already described, as is believed by the greater number of recent observers, or whether there is not likewise, as is held by Henle and Chrzonszczewsky, a set of small anastomosing tubules, some of which may have blind extremities.

Fig. 655.

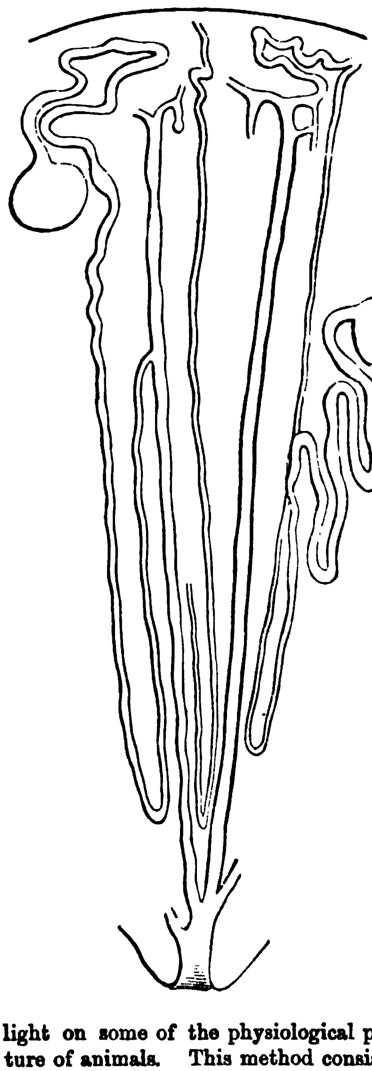


Fig. 655.—Diagram of the Looped Uriniferous Tubes and their Connection with the Capsules of the Glomeruli (from Southey after Ludwig).

In the lower part of the figure one of the larger branching tubes is shown opening on a papilla; in the middle part three of the looped small tubes are seen descending to form their loops, and reascending in the medullary substance; while in the upper or cortical part two of these tubes, after some enlargement, are represented as becoming convoluted and dilated in the capsules of glomeruli.

According to Schweigger-Seidel the limbs of the looped tubes are always of unequal size, that which is continued into the intermediate tubes being the larger of the two; and he divides the loops into two sorts, one in which the narrowest portion forms the loop, and another in which, at the loop, the tube is of the diameter of the larger of its two limbs. He likewise points out the existence of occasional capsular dilatations, where the looped tubes meet the intermediate portions, which, as he remarks, may explain the statement of Moleschott, that he had found in mammals capsules communicating with two tubules.

The investigations of Chrzonszczewsky deserve special mention, on account of the novel method to which he resorted for the verification of his views, and which promises to throw much light on some of the physiological processes as well as on the minute structure of animals. This method consists in the introduction of the colouring matter with which the observed vessels are to be filled into the system of a living animal, either by direct infusion into the blood, or along with food into the alimentary canal, or by absorption from any of the larger serous cavities. The results of this mode of colouring the vessels and ducts

have already been noticed in its application to the liver. For the kiduey Chrzonszczewsky made use of the carminate of ammonia, which is freely eliminated with the urine. In order to obtain a full colouring of the bloodvessels, first the renal veins, and afterwards the arteries, are tied soon after a certain portion of the coloured fluid has been introduced into the jugular vein of the living animal. To obtain a coloured injection of the uriniferous tubes, the animal is allowed to live for about an hour after the introduction of the carmine liquid, and then the ureters are tied, while the renal bloodvessels are carefully washed out with a weak solution of common salt; and to preserve the specimens from after infiltration of the colour, they are immersed in absolute alcohol acidulated with glacial acetic acid.

Fig. 656.

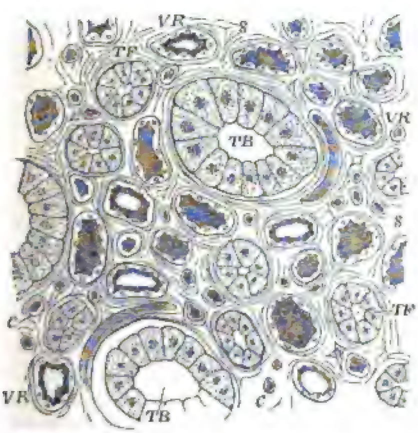


Fig. 657.

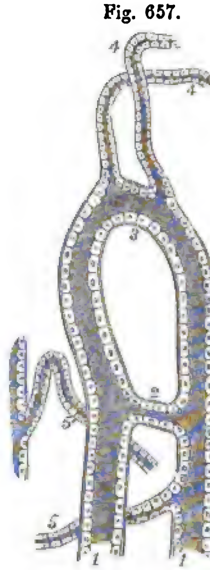


Fig. 656.—Transverse Section of the Medullary Substance of the Pig's Kidney (from Chrzonszczewsky). $\frac{300}{1}$

The drawing represents a small portion of the kidney of an animal into which colouring matter had been infused during life so as to fill the bloodvessels, by which means the distinction between them and the uriniferous tubes both larger and smaller is established, as well as by the different character of the lining epithelium; the section is made near the papilla; TB, the larger uriniferous tubes or tubes of Bellini; TF, the smaller uriniferous tubes or looped tubes of Henle, named by Chrzonszczewsky tubes of Ferrein; VR, the vasa recta or larger bloodvessels; C, the small vessels and capillaries; S, the stroma.

Fig. 657.—Larger and Smaller Uriniferous Tubes from the Medullary Substance of the Pig's Kidney (from Chrzonszczewsky).

1, 1, two of the larger tubes, connected by a transverse tube at 2, and presenting a looped arrangement at 3; from this place two smaller uriniferous tubes, 4, 4, are seen taking their origin, as well as at the other places, 5, 5.

Bloodvessels.—The kidneys are highly vascular, and receive their blood from the right and left renal arteries (p. 414), which are very large in proportion to the size of the organs they supply. Each renal artery divides into four or five branches, which, passing in at the hilus, between the vein

and ureter, may be traced into the sinus of the kidney, where they lie amongst the infundibula, together with which they are usually imbedded in a quantity of fat. Penetrating the substance of the organ between the papillæ, the arterial branches enter the cortical substance found in the intervals between the medullary cones, and go on, accompanied by a sheathing of areolar tissue derived from the proper coat, and dividing and subdividing, to reach the bases of the pyramids, where they form arches between the cortical and medullary parts, which however are not complete, and in this respect differ from the freely anastomosing venous arches which accompany them. From the arches smaller *interlobular*

Fig. 658.

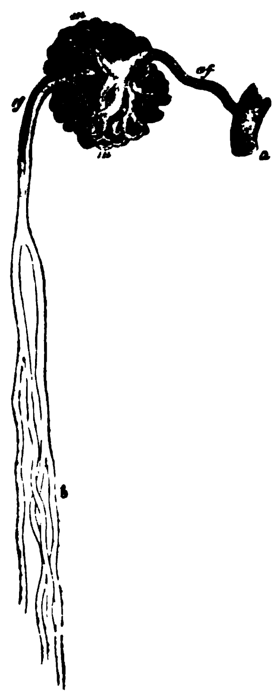


Fig. 658.—INJECTED GLOMERULUS FROM THE INNER PART OF THE CORTICAL SUBSTANCE OF THE HORSE'S KIDNEY (from Kölliker after Bowman). 70/1

a, interlobular artery; *af*, afferent artery; *m m*, convoluted vessels of the glomerulus; *ef*, efferent or straight arteriole; *b*, its subdivision in the medullary substance.

arteries are given off, which pass outwards between the double layers of Malpighian capsules which intervene between the pyramids of Ferrein; and from these interlobular arteries are derived the afferent arteries of the glomeruli. The renal arteries give branches likewise to the capsule of the kidney which anastomose with branches of the lumbar arteries, and that so freely that Ludwig was able partially to inject the kidneys of a dog from the aorta after the renal arteries had been tied. (See also Turner as cited at p. 417.) Within the glomerulus the afferent artery breaks up into convoluted branches of capillary minuteness, which are gathered together again to form the efferent vessel. The efferent vessel is so far comparable with the vena portæ of the liver that it breaks up again into capillaries, which form a close honeycomb network surrounding the convoluted tubules, and a less copious network with elongated meshes round the straight tubes of the cortical substance. Within the medullary substance are found numbers of straight vessels, *vasa recta*, which lie between the uriniferous tubes, and at the bases of the Malpighian pyramids are arranged in bundles extending inwards from between the pyramids of Ferrein. These vessels partly break up into capillaries, from which returning veins arise, and partly, as has been already noticed, form loops similar to those of the looped tubules of Henle. The mode in which the vasa recta take origin has been made the subject of considerable discussion. According to Bowman, Kölliker, and Ludwig and Zuwarykin, the vasa efferentia from the innermost glomeruli are larger than the others, and break into brushes of these vasa recta. Arnold, Virchow, Beale, and others maintain the direct origin of vasa recta *from* the renal arteries without intervention of the glomeruli. Huschke, Henle

and Hyrtl consider that they take origin in the capillary network of the zone at the base of the pyramids ("neutral zone").

Fig. 659.

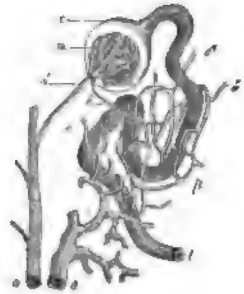


Fig. 659.—Diagram showing the Relation of the Malpighian Body to the Uriniferous Ducts and Bloodvessels (after Bowman).

a, one of the interlobular arteries; *a'*, afferent artery passing into the glomerulus; *m*, vascular tuft formed within the glomerulus; *c*, capsule of the Malpighian body, forming the termination of and continuous with *t*, the uriniferous tube; *e'*, *e'*, efferent vessels which subdivide in the plexus *p*, surrounding the tube, and finally terminate in the branch of the renal vein *e*.

Small veins, arising by numerous venous radicles from the capillary network of the kidney, are seen near the surface of the gland, arranged so as to leave between them minute spaces, which appear nearly to correspond with the bases of the so-called pyramids of Ferrein. These vessels, some of which have a stellate arrangement (*stellulæ*, Verheyen), joined by numerous branches from the fibrous coat of the kidney, end in larger veins, which again unite into arches round the bases of the pyramids of Malpighi. Here they receive the veins of the pyramids which commence in a beautiful plexus round the orifices of the tubuli on the surface of the papillæ. Venous trunks then proceed, in company with the arteries, through the cortical envelope between the pyramids, to the sinus of the kidney. Joining together, they escape from the hilus, and ultimately form a single

Fig. 660.

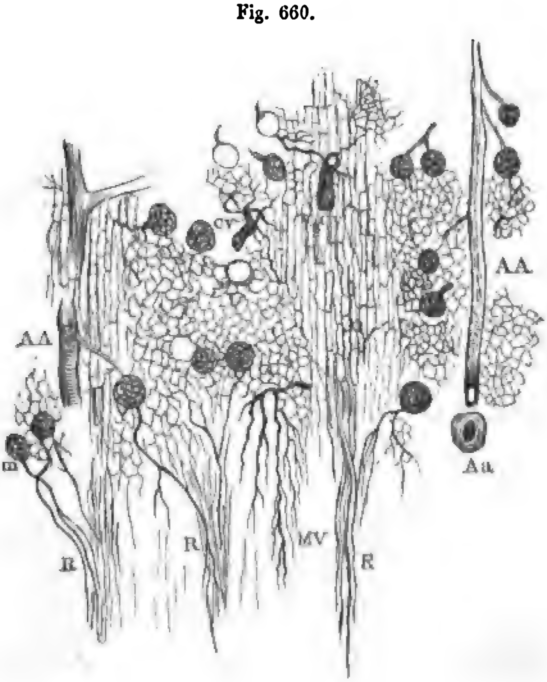


Fig. 660.—Longitudinal Section of a Part of the Tubular Substance and the adjacent Cortical Substance of the Kidney (from Southey).

The bloodvessels have been minutely injected, and the figure is designed principally to show the origin of the vasa recta. A A, ascending arteries divided longitudinally; C V, cortical veins; A *a*, transverse section of anastomotic arch; *m*, Malpighian bodies; R, vasa recta; M V, medullary veins.

vein, which lies in front of the artery, and ends in the inferior vena cava (p. 474).

Nerves.—The nerves which have been traced into the kidneys are small. They come immediately from the renal plexus and the lesser splanchnic nerve, and contain filaments derived from both the sympathetic and cerebro-spinal systems. They may be traced accompanying the arteries to their finer branches, but it is uncertain how they end.

Intertubular Stroma.—Between the tubules and vessels of the kidney, although they are disposed closely together, a certain very small amount of interstitial matrix exists, first described by Goodsir, then by Bowman and others, and to which attention has latterly been paid by a number of observers, and especially by Beer. This matrix is for the most part nearly homogeneous, but has a more fibrous character in the vicinity of the ramifications of the bloodvessels. Fibres are likewise described by Ludwig and Zawarykin as passing round the Malpighian corpuscles, and others have been seen by Henle, coiling round the tubes of the medullary substance. The stroma is more abundant in the cortical substance than in the greater part of the medullary; but according to Henle it is very abundant towards the apices of the papillæ. Nuclei and connective tissue corpuscles are scattered through its substance. It is much more abundant in animals than in man, and in the human kidney it is more apparent in the young than in the adult, and is also much richer in corpuscles; in this respect resembling the connective tissue generally.

Absorbents.—The lymphatics of the kidney are numerous, consisting of a superficial set, and of deep lymphatics which issue from the hilus with the bloodvessels. According to the researches of Ludwig and Zawarykin, the stroma of the kidney forms a thick network of freely intercommunicating lymphatic spaces, guided to the surface along the tissue round the bloodvesels. These spaces are similar to those previously found by Ludwig and Tomsa in the testicle, and held by His to possess epithelial walls. They are most abundant in the cortical substance.

Among *writings on the kidney*, the following may be here referred to:—Bowman, in Philos. Trans. 1842; Toynbee, in Medico-Chir. Trans. 1846; Gerlach, in Müller's Archiv, 1845; Johnson, article Ren, in Cyclopædia of Anat. and Phys.; Isaacs, in Trans. New York Acad. of Medicine, vol. i., 1857; Henle, Zur Anatomie der Niere, Göttingen, 1862, and in Handbuch; Ludwig and Zawarykin, in Wiener Kais. Acad. Sitzungsbericht, vol. xlviii. 1864; Chrzonszczewsky, in Virchow's Archiv, xxxi. 1864; Schweigger-Seidel, Die Niere des Menschen und der Saügethiere, Halle, 1865; Southey, in St. Bartholomew's Hosp. Reports, 1865; also, on the stroma, Goodsir, in Lond. and Edin. Journ. of Med. Science, May, 1842; and Beer, Die Bindesubstanz d. Menschlichen Niere, Berlin, 1859.

Development.—The development of the kidneys, and also that of the suprarenal capsules will be described later with that of the genito-urinary organs.

The Urine.—This is a complex and somewhat variable fluid, containing in solution animal substances characterised by having a large amount of nitrogen in their composition, and derived, it would seem, from the waste of the tissues; also saline substances, and adventitious matters which have been introduced into the blood. The average quantity secreted daily is from 30 to 40 fluid ounces. Its specific gravity varies in health from 1·015 to 1·030, the average standard being 1·020. It is slightly acid in its reaction, and contains some mucus and epithelium. A thousand parts of ordinary urine usually contain 933 parts of water, and 67 of solid matter. The researches of Bowman upon the structure of the kidney in man and animals, render it probable that the solid urinary constituents are secreted by the tubuli, and that the watery part of the urine simply transudes through the vessels of the glomeruli.

The following analysis of the solid contents of the urine is from Lehmann, but it

must be considered approximative only, since the proportion of the ingredients is liable to great variation in dependence upon food, exercise, and other conditions:—

Urea	49·68
Uric acid	1·61
Extractive matters, ammoniacal salts, and chloride of sodium	28·95
Alkaline sulphates	11·58
Alkaline phosphates	5·96
Phosphates of lime and magnesia	1·50
	99·28

Among the extractive matters are kreatine, kreatinine, and hippuric acid.

SUPRARENAL BODIES.

The *suprarenal bodies* or *capsules*, or suprarenal glands, (capsulæ atrabiliariæ seu renes succenturiati of old anatomists), are two flattened bodies, each of which has a somewhat crescentic or bent triangular shape, and surmounts the corresponding kidney. The *upper* border, convex and thin, is often considerably elevated in the middle so as to form two sides of a triangle. The lower border is concave, and rests upon the anterior and inner part of the summit of the kidney, to which it is connected by loose areolar tissue: it is thick, and almost always deeply grooved. The *posterior* surface rests upon the diaphragm. Its *anterior* surface is covered on the right side by the liver, and on the left by the pancreas and spleen: it presents an irregular fissure named the *hilus*, from which the suprarenal vein emerges. The right capsule, like the right kidney, is placed lower down than the left.

The suprarenal capsules vary in size in different individuals, and the left is usually somewhat narrower at its base, but longer from above downwards, and larger than the right. They measure from an inch and a quarter to an inch and three-quarters in height, and about an inch and a quarter in width; their thickness is from two to three lines. The *weight* of each in the adult is from one to two drachms.

Besides a covering of areolar tissue mixed frequently with much fat, the suprarenal capsules have a thin fibrous investment. Externally, they have a yellowish or brownish-yellow colour. When divided, they are seen to consist of two substances: one, *external* or *cortical*, is of a deep yellow colour, firm and striated, and forms the principal mass of the organ; the other, *internal* or *medullary*, is in the adult of a dark brownish-black hue, and so soft and pulpy that some anatomists have erroneously described a cavity within it.

The *fibrous investment* is so intimately connected with the deeper parts that it cannot be removed without lacerating the subjacent structure. Its deeper layers are destitute of elastic fibres, and are particularly rich in nuclei: they are continuous with the septa which enter into the formation of the substance of the organ.

The *cortical part* of the suprarenal body, examined with a low magnifying power, is seen to consist of stroma, in which are imbedded columnar and reticulated masses measuring on an average $\frac{1}{700}$th of an inch in diameter, arranged vertically to the surface of the organ, and containing cellular constituents. In the deepest part of the cortex, however, the colour is darker, and the columnar arrangement is lost, the stroma being more equally scattered; and immediately beneath the fibrous coat there is another very narrow layer in which the stroma forms oval spaces, of which it is difficult to say whether they communicate with the extremities of the columns or not. These inner and outer layers have been named by J. Arnold respectively zona reticularis and zona glomerulosa, while he applies the term

zona fasciculata to the main part; but as the transition from one of these parts to another is not sudden nor indicated by any line of demarcation, they

Fig. 661.

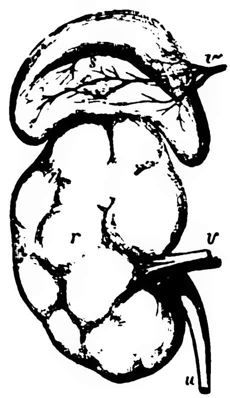


Fig. 662.

A.

B.

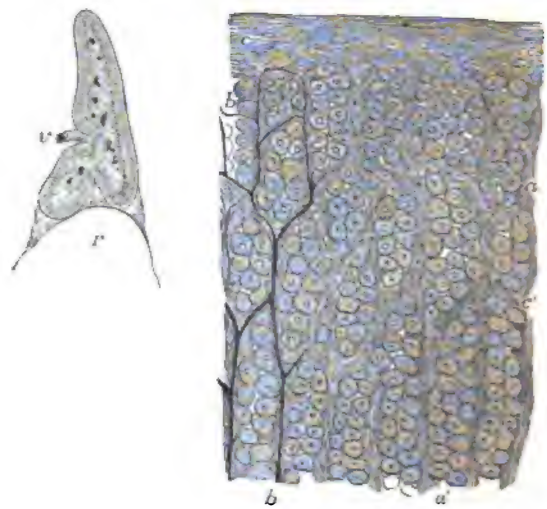


Fig. 661.—Front view of the Right Kidney and Suprarenal Body of a full grown Fœtus.

This figure shows the lobulated form of the fœtal kidney *r*; *v*, the renal artery and vein; *u*, the ureter; *s*, the suprarenal capsule, the letter is placed near the sulcus in which the large veins (*v'*) are seen dividing and dipping into the interior of the organ.

Fig. 662.—Sections of the Suprarenal Body.

A, Vertical section of the suprarenal body of a fœtus twice the natural size, showing the lower notch by which it rests on the summit of the kidney, and the anterior notch by which the veins penetrate, together with the distinction between the medullary and cortical substance. $\frac{2}{1}$

B, longitudinal section of the cortical substance, showing the capsules containing nucleated cells and intervening bloodvessels. $\frac{250}{1}$ The figure represents a small fragment of a section made perpendicularly to the surface in a suprarenal body of which the bloodvessels were partially injected. *a*, one of the superficial masses of cells (in the zona glomerulosa of J. Arnold); *a'*, one of the longer masses slightly deeper (zona fasciculata); *b*, bloodvessels running in the septa of connective tissue between the cell-masses in a part of the specimen; *c*, connective tissue and sheath substance on the surface; *c'*, connective tissue of the septa: this figure, though true to nature in the representation of the several textures, is so far diagrammatic that the space occupied by the shorter masses of cells towards the surface is proportionally too small.

are probably only modifications of the same structure. The contents of the stroma consist of nucleus-like bodies from $\frac{1}{6000}$th to $\frac{1}{3000}$th of an inch in diameter, mixed with minute yellowish granules, and oily particles with granular matter adhering to them, together with large groups of closely-set nucleated cells containing granular matter and oily molecules. The cells vary from $\frac{1}{2000}$th to $\frac{1}{1350}$th of an inch in size, and their opposing sides are somewhat flattened, giving them the form of irregular polyhedra: the larger cells are most loaded with oil globules. In many instances probably the appearance of free nuclei and oil globules is to be explained by cell-walls being ruptured or remaining unrecognised.

According to Simon the columns consist of distinct tubes with a limiting membrane; Ecker and others affirm that no continuous tubular cavities exist, but that rows of closed vesicles, many of them oval in shape, and over-lapping each other, are placed in such manner as to resemble tubes; while Gray believes that the walls of adjoining vesicles are sometimes removed by absorption, so that tubular cavities are formed by the coalescence of neighbouring vesicles. Kölliker, however, and other observers, maintain with more correctness, that the so-called vesicles are merely loculi or cavities in the stroma of the organ, possessing no distinct limitary membrane, and producing the appearance of a tubular structure by their apposition in linear series. The small arteries, entering from the surface, run parallel to these columns, frequently anastomose together between them, and surround each row of vesicles with a fine capillary network. Small bundles of nerves pass inwards in the septa between the columns to reach the medullary part of the organ, and their fibres begin to spread out in the zona reticularis, but do not appear to be distributed to the cortical substance.

The *medullary part* of the suprarenal capsule is separated from the cortical part by a layer of connective tissue, the fibres of which are parallel to the two parts, and allow them to be easily separated one from the other in sections prepared for the microscope. In the thinner parts of the adult organ there is no medullary part, or it has shrunk away, and the layer of connective tissue referred to is found separating the deep surfaces of two opposed portions of the cortical part; but in the young state the distinction of cortical and medullary probably extends throughout the whole. The medullary part is traversed in the centre by venous trunks, which receive the whole of the blood which has passed through the organ. The stroma is delicate, arranged in a reticular manner; the pulpy substance which lies in it is difficult of examination, but consists of cells, differing from those of the cortex in being destitute of oil globules, and some of them branched. The bundles of nerves which pass through the cortical substance run between it and the medullary substance, and then form a copious interlacement which extends through the whole of the medullary stroma. According to Leidig and Luschka, the cells of the medullary substance are ganglionic; and Luschka states that he has found them both connected one with another and with nerve fibres; but this view still requires confirmation. Moers, while he denies that the cells of the medullary parenchyma are nervous, describes ganglia on the nerves where their bundles begin to break up. The medullary substance receives its blood by the continuation inwards of the capillary network of the cortex, the blood from which is collected by venous radicles which open into the stems in the centre of the organ.

Vessels.—The suprarenal bodies receive *arteries* from three sources, viz., from the aorta, the phrenic, and the renal arteries. The distribution of their capillary vessels has already been mentioned.

The *veins*, which pass out from the centre, are usually united into one for each organ. The right vein enters the vena cava inferior immediately, whilst the left, after a longer course, terminates in the left renal vein.

The *lymphatics* are imperfectly known. Kölliker has seen a few small trunks upon the surface; and Luschka has, in addition, observed others emerging from the interior in company with the vein.

Nerves.—The nerves are exceedingly numerous. They are derived from the solar plexus of the sympathetic, and from the renal plexuses. According to Bergmann, some filaments come from the phrenic and pneumogastric nerves. They are made up mainly of dark-bordered white fibres, of different sizes, and they have many small

ganglia upon them before entering the organ. The nerves are especially numerous in the lower half, and inner border.

Accessory suprarenal capsules are occasionally met with, attached by connective tissue to the main bodies; and varying from a small size up to that of a pea. According to Duckworth, they possess no medullary part.

On the subject of the suprarenal capsules may be consulted,—Ecker, Der feinere Bau der Nebennieren, Braunschweig, 1846; Simon on the Thymus Gland; Frey, article "Suprarenal Capsules," in Cyclop. of Anat. and Phys.; Harley, in the Lancet, June, 1858; Duckworth, in St. Bartholomew's Hosp. Reports, 1865; Moers, in Virchow's Archiv, 1864, vol. xxix. p. 336; J. Arnold, Virchow's Archiv, 1866, vol. xxxv. p. 64; Leidig, Kölliker, Luschka, and Henle, in their Handbooks.

Function.—Nothing is known positively with regard to the functions of the suprarenal capsules. The opinion which has met with most acceptance among physiologists is that these bodies belong to the class of blood-vascular glands, and exert some influence upon the elaboration or disintegration of nutritive material. Bergmann, however, who was the first to point out the richness of their nervous supply, suggested that they were parts of the sympathetic nervous system, and in this opinion he has been followed by Leidig and Luschka; while Kölliker states that, upon anatomical grounds, he is inclined to consider the cortical and medullary portions as functionally different; the former belonging to the group of vascular or ductless glands, the latter appearing to be an apparatus appertaining to the nervous system. Brown-Séquard found that injuries to the spinal cord in its dorsal region produced congestion and subsequent hypertrophy of the suprarenal bodies. Addison has shown that a bronzed tint of skin, together with progressive emaciation and loss of strength, is to be found in conjunction with various forms of disease more or less involving and altering the structure of these bodies.

THE URETERS.

The *ureters* are two tubes which conduct the urine from the kidneys into the bladder. The upper, dilated, funnel-shaped commencement of each in the pelvis of the kidney, into which the calyces pour their contents, has already been described. Towards the lower part of the hilus of the kidney the pelvis becomes gradually contracted, and opposite the lower end of the gland, assuming the cylindrical form, receives the name of ureter. These tubes extend downwards to the posterior and under part or base of the bladder, into which they open, after passing obliquely through its coats.

The ureters measure from fourteen to sixteen inches in length, and their ordinary width is about that of a goose-quill. They are frequently, however, dilated at intervals, especially near their lower end. The narrowest part of the tube, excepting its orifice, is that contained in the walls of the bladder.

Each ureter passes, at first, obliquely downwards and inwards, to enter the cavity of the true pelvis, and then curves forwards, and inwards, to reach the side and base of the bladder. In its whole course, it lies close behind the peritoneum, and is connected to neighbouring parts by loose areolar tissue. Superiorly, it rests upon the psoas muscle, and is crossed, very obliquely from within outwards, below the middle of the psoas, by the spermatic vessels, which descend in front of it. The right ureter is close to the inferior vena cava. Lower down, the ureter passes over the common iliac, or the external iliac vessels, behind the termination of the ileum on the right side and the sigmoid flexure of the colon on the left. Descending into the pelvis, it enters the fold of peritoneum forming the corresponding posterior false ligament of the bladder, and reaching the side of the bladder near the base, runs downwards and forwards in contact with it, below the obliterated hypogastric artery, and is crossed upon its inner side, in the male,

by the vas deferens, which passes down between the ureter and the bladder. In the female, the ureters run along the sides of the cervix uteri and upper part of the vagina before reaching the bladder.

Having reached the base of the bladder, about two inches apart from one another, the ureters enter its coats, and running obliquely through them for about three-quarters of an inch, open at length upon the inner surface by two narrow and oblique slit-like openings, which are situated, in the male, about an inch and a half behind the prostate, and about the same distance from each other. This oblique passage of the ureter through the vesical walls, while allowing the urine to flow into the bladder, has the effect of preventing its return up the ureter towards the kidney.

Structure.—The walls of the ureter are pinkish or bluish white in colour. They consist externally of a dense, firm, areolar, and elastic coat, which in quadrupeds decidedly contracts when artificially irritated. According to Huschke, it possesses two layers of longitudinal fibres: Henle finds only an inner longitudinal and an outer circular layer; while Kölliker, who formerly described the circular and outer longitudinal layers as the only layers found except in immediate proximity to the bladder, now admits the inner longitudinal and circular as the principal layers, on Henle's authority, and states that the longitudinal fibres external to the circular layer are absent at the upper part of the tube.

Fig. 663.

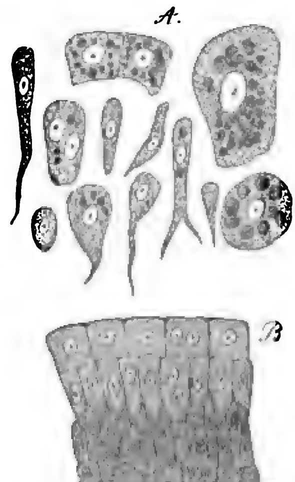


Fig. 663.—Epithelium from the Pelvis of the Human Kidney (from Kölliker). $\frac{350}{1}$

A, different kinds of epithelial cells separated; B, the same in situ.

Internally, the ureter is lined by a thin and smooth *mucous membrane*, which presents a few longitudinal folds when the ureter is laid open. It is prolonged above upon the papillæ of the kidney, and below becomes continuous with the lining membrane of the bladder. The epithelium is of the spheroidal or transitional character, stratified, and containing, besides rounded cells, others cylindrical and branched (Kölliker and Luschka).

Vessels.—The ureter is supplied with blood from small branches of the renal, the spermatic, the internal iliac, and the inferior vesical arteries. The veins end in various neighbouring vessels.

The *nerves* come from the inferior mesenteric, spermatic, and hypogastric plexuses.

Varieties.—Sometimes there is no funnel-shaped expansion of the ureter at its upper end into a pelvis, but the calyces unite into two or more narrow tubes, which afterwards coalesce to form the ureter. Occasionally, the separation of these two tubes continues lower down than usual, and even reaches as low as the bladder, in which case the ureter is double. In rare cases, a triple ureter has been met with.

In instances of long-continued obstruction to the passage of the urine, the ureters occasionally become enormously dilated, and their opening into the bladder becomes direct so as to lose its valvular action.

THE URINARY BLADDER.

The *urinary bladder* (vesica urinaria) is a hollow membranous and muscular viscus, which receives the urine poured into it through the ureters, retains it for a longer or shorter period, and finally expels it through the urethra.

During infancy it is pyriform, and lies chiefly in the abdomen, but in the adult it is situated in the pelvic cavity behind the pubes, and in the male, in front of the rectum ; in the female it is separated from the rectum by the uterus and vagina.

The size and shape of the bladder, its position in the abdomino-pelvic cavity, and its relations to surrounding parts, vary greatly, according to its state of distension or collapse. When quite empty, the bladder lies deeply in the pelvis, and in a vertical antero-posterior section presents a triangular appearance, being flattened before and behind, having its base turned downwards

Fig. 664.

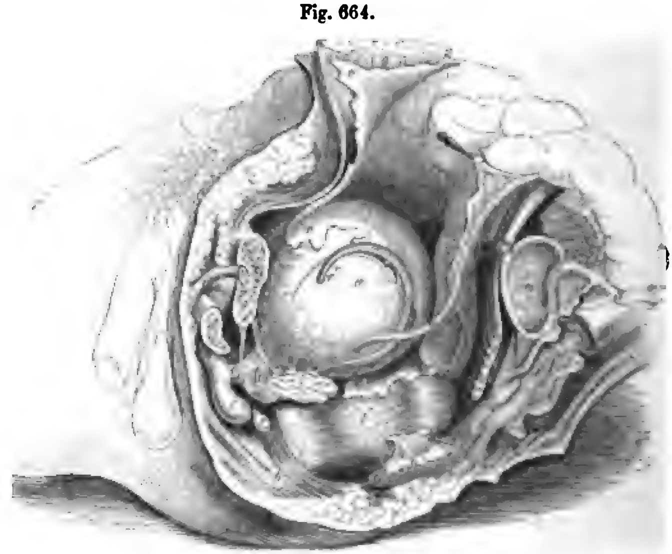


Fig. 664.—Lateral View of the Viscera of the Male Pelvis (after Quain). $\frac{1}{4}$

The left os ilium has been disarticulated from the sacrum, the spinous process of the ischium cut through, and the pubes divided to the left of the symphysis : *a*, the bladder ; *b*, *b′*, the rectum ; *c*, membranous part of the urethra ; *d*, section of the left crus or corpus cavernosum ; *e*, bulb of the spongy body of the urethra ; *f*, Cowper's gland ; *g*, section of the body of the pubes ; *h*, sphincter ani muscle ; *i*, part of the left vas deferens ; *m*, articular surface of the sacrum ; *n*, divided spine of the ischium ; *o*, coccyx ; *p*, prostate gland ; *r*, *r*, peritoneum ; *r′*, recto-vesical pouch ; *u*, left ureter ; *v*, left vesicula seminalis.

and backwards, whilst its apex reaches up behind the symphysis pubis (fig. 601). The surfaces named anterior and posterior have thus a considerable inclination. When moderately full, it is still contained within the pelvic cavity, and has a rounded form ; but when completely distended, it rises above the brim of the pelvis, and becomes egg-shaped ; its larger end, which is called the *base* or *inferior fundus*, being directed towards the rectum in

in the male and the vagina in the female; and its smaller end, or *summit*, resting against the lower part of the anterior wall of the abdomen. Immediately in front of the base is the thickened portion named the *cervix*, or *neck*, which bounds the outlet of the bladder, and connects it below with the urethra.

The long axis of the distended bladder is inclined obliquely upwards and forwards from the base to the summit, in a line directed from the coccyx to a point between the pubes and the umbilicus. In being gradually distended, the bladder curves slightly forwards, so that it becomes more convex behind than in front, and its upper end is by degrees turned more and more towards the front of the abdomen. Lastly, the bladder, when filled, appears slightly compressed from before backwards, so that its diameter in that direction is less than from side to side. Kohlrausch states that when the bladder is filled during life, it has the shape of a flattened spheroid; and that, owing to pressure of the intestines from above, and the gravitation of fluid in its interior, its vertical diameter is the shortest. In its ordinary state the longest diameter in the male is from base to summit; but in the female its breadth is often greater than its height. The average capacity of the bladder is often stated to be greater in the female than in the male; and, no doubt, instances of very large female bladders are not unfrequent, but these have probably been the result of unusual distension: in the natural condition, according to Luschka and Henle, the female bladder is decidedly smaller than that of the male.

While freely movable in all other directions upon surrounding parts, the bladder is fixed below to the walls of the pelvis by the neck, and by reflections of the recto-vesical fascia, named the *true ligaments* of the bladder. It is supported, moreover, by strong areolar connections with the rectum or vagina, according to the sex, also in a slighter degree by the two ureters, the obliterated hypogastric arteries and the *urachus*, by numerous blood-vessels, and, lastly, by a partial covering of the peritoneum, which, in being reflected from this organ in different directions, forms certain folds or duplicatures, named the *false ligaments* of the bladder.

The *anterior* surface is entirely destitute of peritoneum, and is in apposition with the triangular ligament of the urethra, the sub-pubic ligament, the symphysis and body of the pubes, and, if the organ be full, the lower part of the anterior wall of the abdomen. It is connected to these parts by loose areolar tissue, and to the back of the pubes by two strong bands of the vesical fascia, named the *anterior* true ligaments. This surface of the bladder may be punctured above the pubes without wounding the peritoneum.

The *posterior surface* of the bladder is entirely free, and covered everywhere by the peritoneum, which in the male is prolonged also for a short distance upon the base of the bladder. In the male, this surface is in contact with the rectum, and in the female with the uterus, some convolutions of the small intestine descending between it and those parts, unless the bladder be very full. Beneath the peritoneum, in the male, a part of the vas deferens is found on each side of the lower portion of this surface.

The *summit* (sometimes named the *superior fundus*) is connected to the anterior abdominal wall by a tapering median cord, named the *urachus*, which is composed of fibro-areolar tissue, mixed at its base with some muscular fibres which are prolonged upon it from the bladder. This cord, becoming narrower as it ascends, passes upwards from the apex of the bladder between the linea alba and the peritoneum, to reach the umbilicus,

where it becomes blended with the dense fibrous tissue found in that situation. The urachus, which forms in the early fœtal state a tubular communication between the urinary bladder and the allantoid vesicle, preserves, according to Luschka, vestiges of its original condition in the form of a long interrupted cavity, with irregularities and dilatations, lined with epithelium similar to that of the bladder, and sometimes communicating by a fine opening with the vesical cavity (Virchow's Archiv., 1862, and Anat. d. Mensch., vol. ii., p. 229).

The *sides* of the bladder, when it is distended, are rounded and prominent, and are each of them crossed obliquely by the cord of the obliterated hypogastric artery, which is connected posteriorly with the superior vesical artery, and runs forwards and upwards to the umbilicus, approaching the urachus above the summit of the bladder. Behind and above this cord the side of the bladder is covered with the peritoneum, but below and in front of it the peritoneum does not reach the bladder, which is here connected to the sides of the pelvic cavity by loose areolar tissue containing fat, and, near its anterior and lower part, by the broad expansion from the recto-vesical fascia, forming the lateral true ligament. The vas deferens crosses obliquely the lower part of this lateral surface, from before backwards and downwards, and turning over the obliterated hypogastric artery, descends upon the inner side of the ureter, along the posterior surface, to the base of the bladder.

Fig. 665.

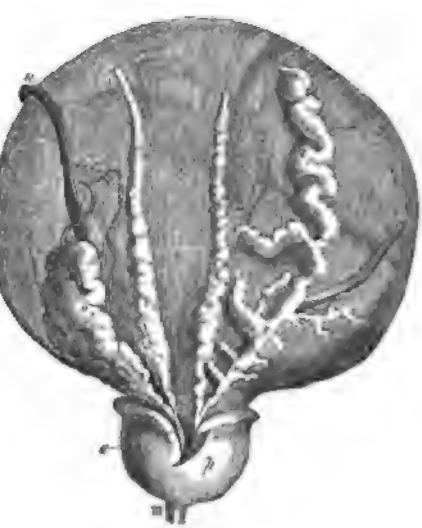


Fig. 665.—Base of the Male Bladder with the Vesiculæ Seminales, Vasa Deferentia and Prostate exposed (from Haller). ½

a, line of reflection of the peritoneum in the recto-vesical pouch; *b*, the part above this from which the peritoneum has been removed, exposing the longitudinal muscular fibres; *i*, left vas deferens ending in *e*, the left ejaculatory duct; *s*, left vesicula seminalis joining the same duct; the right vas deferens, and the right vesicula seminalis, marked *s*, *s*, unravelled, are also shown; *p*, under side of the prostate gland; *m*, small part of the membranous portion of the urethra; *u*, *u*, the ureters, of which the right is turned to the side.

The *base* or *fundus* (inferior fundus) is the widest part of the bladder. It is directed backwards as well as downwards, and differs according to the sex in its relations to other parts. In the *male* it rests upon the second portion of the rectum, and is covered posteriorly for a short space by the peritoneum, which, however, is immediately reflected from thence upon the rectum, so as to form the *recto-vesical pouch*. In front of the line of reflection of the serous membrane, the base of the bladder is destitute of peritoneum, and adherent to the rectum by dense fibro-areolar tissue

over the extent of a triangular area bounded at the sides by the vasa deferentia and vesiculæ seminales, whilst its apex in front reaches the prostate gland. It is in this space, which in the natural state of the parts is by no means so large as it appears after they are disturbed in dissection, that the bladder may be punctured from the rectum without injury to the peritoneum. In the *female*, the base of the bladder is of less extent, and does not reach so far back in the pelvis as in the male; for it rests against the front of the neck of the uterus and the anterior wall of the vagina, both of which organs intervene between it and the rectum. This part of the bladder adheres to the vagina, and above that adhesion the peritoneum forms a pouch between it and the uterus, much shallower than the recto-vesical pouch of the male.

The *cervix* or *neck* of the bladder is a term commonly applied to the part of the bladder at which the cavity terminates in the urethra, and is often indefinitely used, so as to include a considerable portion either of the bladder or urethra. It may be conveniently retained to denote the region of the immediate neighbourhood of the urethral orifice. It is the most strongly muscular part of the bladder, and in the male it is closely connected with the base of the prostate gland, by which it is supported. It was formerly described as an infundibular projection, but, as pointed out by Kohlrausch, no such arrangement exists. The urethral orifice is in both sexes the part of the bladder which in the erect posture is lowest; it lies at the angle of meeting of the base and the anterior surface.

It was formerly believed that the base was the lowest part of the bladder in the adult male, and hence the origin of the term. The inferior position of the urethral orifice was supposed to be peculiar to women and children. The more correct views, however, now entertained with respect to the inclination of the pelvis (p. 98), have led to altered notions of the relative elevation of the pelvic viscera. A consideration of the following circumstances will aid the formation of an accurate conception of the position of the vesical outlet. The symphysis pubis is placed very obliquely; the ischial tuberosities are little lower than the inferior margin of the symphysis pubis, and the triangular ligament is therefore almost horizontal; the lower part of the sacrum and the coccyx are nearly vertical, being only slightly curved forwards, and the tip of the coccyx is on a somewhat higher level than the inferior margin of the symphysis pubis; the curve and position of the rectum are determined by those of the sacrum and coccyx, until it passes in front of the coccyx, when it turns vertically downwards; the prostate gland, situated entirely on the upper or deep side of the triangular ligament, rests on the last turn of the rectum, and the base of the bladder is in contact with the rectum above that place.

Ligaments of the bladder.—The *true ligaments* of the bladder, four in number, two anterior and two lateral, all derived from the vesical portion of the recto-vesical fascia, have been already described (p. 260).

The *false ligaments* or *peritoneal folds* are described as five in number. Two of them, named *posterior false ligaments* or *recto-vesical* folds, run forwards in the male along the sides of the rectum to the posterior and lateral aspect of the bladder, and bound the sides of the recto-vesical cul-de-sac. In the female these posterior folds pass forwards from the sides of the uterus, and are comparatively small. The two *lateral* false ligaments extend from the iliac fossæ to the sides of the bladder, each separated from the corresponding posterior ligament by a prominent angle in which the obliterated hypogastric artery lies. The *superior* false ligament (ligamentum suspensorium) is the portion of peritoneum between the ascending parts of the epigastric arteries, and reaches from the summit of the bladder to the umbilicus.

Interior of the Bladder.—On opening the bladder, its internal surface is found to be lined by a smooth membrane, which is so loosely attached to the other coats, that in the flaccid condition of the organ it is nearly everywhere thrown into small wrinkles or folds, which disappear as soon as the bladder is distended. Besides these, the interior of the bladder is often marked by reticular elevations or ridges, corresponding with the fasciculi of the muscular coat.

At the lower and anterior part of the bladder is seen the *orifice* leading into the urethra, round which the mucous membrane is corrugated longitudinally. Immediately behind the urethral opening, at the anterior part of the fundus, is a small smooth triangular surface, having its apex turned forwards, which, owing to the firmer adhesion of the mucous membrane to the subjacent tissues, never presents any rugæ, even when the bladder is empty. This surface is named the *trigone* (trigonum vesicæ, Lieutaud); at its posterior angles are the orifices of the two ureters, situated about an inch and a half from each other, and nearly the same distance from the anterior angle, where the bladder opens into the urethra (fig. 673).

The orifices of the ureters, presenting the appearance of oval slits, are directed obliquely forwards and inwards: they are united by a curved elevation which extends generally outwards and backwards beyond them, and which corresponds in position with a muscular band which joins them together and to the neck of the bladder. Proceeding forwards from opposite the middle of this, is another slight elevation of the mucous surface, named the *uvula vesicæ* (luette vesicale), which projects from below into the urethral orifice. In the female, the trigone is small, and the uvula indistinct. In the male, the uvula lies a little in advance of the middle lobe of the prostate, and is sometimes prolonged on the floor of the prostatic portion of the urethra. It is formed by a thickening of the submucous tissue. In its natural state this may contribute to the more perfect closure or apposition of the sides of the orifice of the bladder, and when enlarged by disease it frequently produces serious obstruction at the commencement of the urethra.

Structure.—The bladder is composed of a *serous*, a *muscular*, and a *mucous* coat, united together by areolar tissue, and supplied with numerous blood-vessels and nerves.

The serous or peritoneal coat is a partial covering, investing only the posterior and upper half of the bladder, and reflected from it upon the surrounding parts in the manner already described in detail.

The muscular coat consists of pale unstriped involuntary muscular fibres, so arranged as to warrant the usual description of them as forming layers, the outer of which consists of fibres more or less longitudinal, and the next, of fibres more circular in disposition; while, beneath this, is another delicate longitudinal layer more recently recognised.

The *external* or *longitudinal* fibres are most distinctly marked on the *anterior* and *posterior* surfaces of the bladder. Commencing in front at the neck of the organ, from the pubes in both sexes (musculi pubo-vesicales, p. 265), and, in the male, from the adjoining part of the prostate gland, they may be traced upwards along the anterior surface to the summit of the bladder; and they may likewise be followed down over the posterior surface and base to the under part of the neck of the bladder, where they become attached to the prostate in the male, and to the front of the vagina in the female. Upon the *sides* of the bladder the superficial fasciculi run more or less obliquely, and often intersect one another: in the male they

reach the sides of the prostate. At the summit a few are continued along the urachus. The longitudinal fibres, taken together, constitute what has been named the *detrusor urinæ* muscle.

The so-called *circular* fibres form a thin and somewhat irregular reticulated layer distributed over the body of the bladder, having various appearances in different bladders. Their course may in general be looked upon as transverse, but for the most part throughout the upper two-thirds of the bladder they cross one another in very oblique bands: towards the lower part of the organ they assume a more circular course, and upon the fundus and trigone form a tolerably regular layer. Close to and around the cervix, in immediate connection with the prostate in the male, they densely encircle the orifice and constitute what has been named the *sphincter vesicæ*, which, however, is not distinct from the other fibres.

Fig. 666.

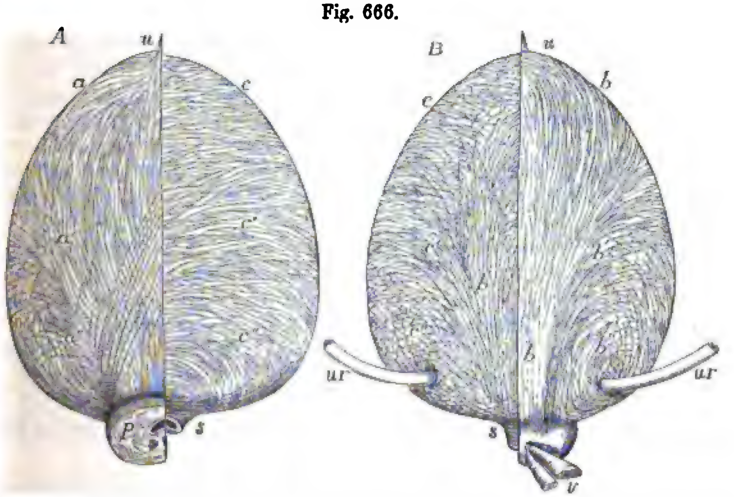


Fig. 666, A.—View of the Muscular Fibres of the Bladder from before (after Pettigrew and from Nature). ½

On the right side the superficial fibres are shown; on the left the deep or circular fibres chiefly are displayed. *a*, on the right side, the median and most superficial bands of the longitudinal fibres, in which a slight decussation of fibres is seen indicating Pettigrew's longest figure-8 loops; *a'*, those diverging somewhat; *a''*, the lowest, which pass much more obliquely; the attachment of the longitudinal fibres to the prostate is shown; on the left side *c*, the upper, *c'*, the middle, and *c''*, the lowest set of circular or deeper fibres; at *s*, the thickest and most transverse sets of these fibres forming the sphincter; *p*, half the prostate left on the right side, the left having been removed; *u*, the urachus, into which some of the longitudinal fibres are seen prolonged.

Fig. 666, B.—View of the Muscular Fibres of the Bladder from behind (after Pettigrew and from Nature). ½

On the right side the superficial fibres are displayed; on the left the deeper fibres of the same kind or intermediate fibres, and some of the circular fibres; *b*, *b*, the median, most superficial and strongest bands of longitudinal fibres on the right side; *b'*, the more diverging set of fibres near the middle of the bladder; *b''*, the most divergent fibres which surround the entrance of the ureters; on the left side, *c*, *c'*, and *c''*, indicate the deeper circular fibres passing round at various levels and crossing with the deeper diverging fibres posteriorly; *s*, the most transverse fibres at the neck forming the sphincter; *u*, the urachus; *ur*, the ureters; the left half of the prostate has been removed to show the sphincter; *v*, part of the right vas deferens and vesicula seminalis.

The *third stratum* of fibres, still more deeply situated, and which might be termed internal longitudinal, was first described by Ellis, who distinguished it as "submucous." It is very delicate, and its fibres, directed longitudinally, are scattered in a regular manner round the cavity of the bladder.

The researches of Pettigrew (including an elaborate series of dissections preserved in the Museum of the Royal College of Surgeons of England) have led him to the conclusion that, with few exceptions, the muscular fibres of all the strata are arranged in figure-8 loops. These loops are directed towards the apex and base, and he regards them as disposed in four sets; an anterior and a posterior set largely developed, and a right and a left lateral set accessory and less fully developed; and they are so arranged that at any one spot on the bladder there are to be found decussating groups of fibres, which may be distinguished as longitudinal, horizontal or transverse, and oblique. The extremities of each figure-8 are placed on one aspect of the bladder, and the point of decussation on the opposite aspect; the arrangement being thus similar to that of a string wound in figure-8 loops round a cylinder. In each set the most superficial loops are compressed laterally and elongated from above downwards, but the succeeding loops as they become more deeply placed are more and more drawn out transversely until those which are nearly circular are reached; and on passing more deeply than these, the loops become again gradually more and more elongated until those which have been alluded to as internal longitudinal are arrived at. The figure-8 arrangement, stated by Pettigrew to exist in all the groups, is most distinctly seen in the anterior set, which may here be more particularly alluded to. The most superficial fibres of this set form a narrow band some of which are prolonged on the urachus, while others pass round close behind its insertion; their decussation takes place about midway between the summit of the bladder and the urethra; and inferiorly they pass forwards to be inserted into the capsule of the prostate, the posterior surface of the pubes, the inner border of the levator ani, and the fascia covering the constrictor urethræ muscle. The points of decussation of the deeper fibres

Fig. 667.

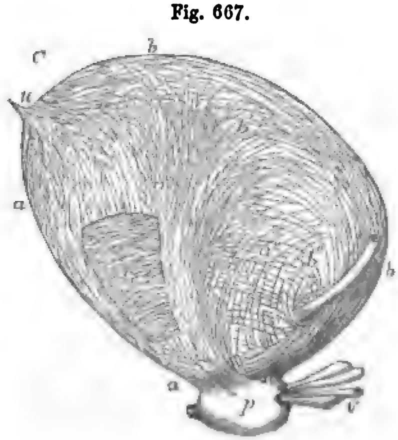


Fig. 667.—View of the Muscular Fibres of the Bladder from the Left Side (after Pettigrew and from Nature). ⅓

The anterior and posterior superficial fibres are seen in profile running from below upwards, crossing each other by their divergence on the sides of the bladder, and are indicated by the same letters as in the previous figures; at *c*, a portion of the anterior longitudinal fibres has been removed so as to expose the deeper circular fibres.

as they become more horizontal, are placed lower and lower down. The fibres which cross obliquely are most expanded, and embrace the larger parts of the bladder, taking part, on the posterior wall, in the formation of the so-called circular layer, while the fibres which at their decussation are more nearly horizontal are confined to the regions of the base and neck. The

whole of the muscular fibres around the prostate and prostatic portion of the urethra are supposed by Pettigrew to be formed by the lower extremities of the various figures-8. The general idea of this figure-8 arrangement was first suggested by Sabatier, by whom the more marked examples of it are described; but it has been fully elaborated by the researches of Pettigrew.

A strong muscular bundle already alluded to passes, as shown by Ellis, with its convexity forwards between the terminations of the ureters, continuous with the longitudinal fibres of these tubes. Other fibres mentioned by Morgagni, and more fully described under the name of the "muscles of the ureters" by Sir C. Bell, pass forwards from the ureters towards the urethra: they are considered by Pettigrew not as special structures, but as a part of the general arrangement of fibres in that part of the bladder.

On the muscular arrangements of the bladder, see Pettigrew, in Phil. Trans. for 1866; Sabatier, Rech. Anat. et Phys. sur les Appareils musculaires correspondants à la vessie et à la prostate dans les deux sexes, 1864; and in Henle's Jahrbericht; Ellis, in Trans. Med. Chir. Society, 1856, and Demonstrations, 1861.

The muscular coat of the bladder forms so irregular a covering, that when the organ is much distended, intervals arise in which the walls are very thin; and should the internal or mucous lining protrude in any spot through the muscular bundles, a sort of hernia is produced, which may go on increasing, so as to form what is called a vesical sacculus, or *appendix vesicæ*, the bladder thus affected being termed *sacculated*. Hypertrophy of the muscular fasciculi, which is liable to occur in stricture of the urethra or other affections impeding the issue of the urine, gives rise to that condition named the *fasciculated* bladder, in which the interior of the organ is marked by strong, reticulated ridges or columns, with intervening depressions.

Next to the muscular coat, between it and the mucous membrane, but much more intimately connected with the latter, is a well-marked layer of areolar tissue, frequently named the *cellular*, or *vascular* coat. This submucous areolar layer contains a large quantity of very fine coiled fibres of elastic tissue.

The mucous membrane of the bladder is soft, smooth, and of a pale rose colour. It is continuous above with the lining membrane of the ureters and kidneys, and below with that of the urethra. It adheres loosely to the muscular tissue, and is thus liable to be thrown into wrinkles, except at the trigone, where it is consequently always more even. It is covered with a stratified epithelium, the particles of which are intermediate in form between those of the columnar and squamous varieties. There are no villi upon the vesical mucous membrane, but it is provided with minute follicles, and small racemose glands lined with columnar epithelium, which are most abundant in the vicinity of the neck of the bladder. The vesical mucus (according to Mandl) is alkaline, and appears to contain alkaline and earthy phosphates.

Vessels.—The *superior vesical* arteries proceed from the remaining pervious portions of the hypogastric arteries; in the adult they appear as direct branches of the internal iliac. The *inferior* vesical arteries are usually derived from the anterior division of the internal iliac. In the female the uterine arteries also send branches to the bladder, The neck and base of the organ appear to be the most vascular portions. The *veins* form large plexuses around the neck, sides and base of the bladder; they eventually pass into the internal iliac veins. The *lymphatics* follow a similar course.

The *nerves* are derived partly from the hypogastric plexus of the sympathetic, and partly from the sacral plexus of the cerebro-spinal system. The former are said to be chiefly distributed to the upper part of the bladder, whilst the spinal nerves may be traced more directly to its neck and base.

THE URETHRA.

The urethra is a membranous tube directed in the median line, first vertically and then from behind forwards, beneath the arch of the pubes, in which situation it opens in the female into the vulva, while in the male it is enclosed in the spongy substance and prolonged beneath the corpora cavernosa penis. In the female, it serves simply as the excretory passage for the urine; in the male, it conducts also the seminal fluid. The detailed anatomy of the male and female urethra will be given with that of the organs of generation of the respective sexes.

ORGANS OF GENERATION.

THE MALE ORGANS OF GENERATION.

The male organs of generation include, together with the *testes* and their proper *excretory apparatus*, a series of structures which for convenience may be considered first, as they are closely connected with the urethra. Thus, at its commencement the urethra passes through the *prostate gland*, and there it receives the excretory ducts of the testes and vesiculæ seminales; emerging from the prostate, it traverses the layers of the subpubic fascia supported by muscles, and, becoming copiously surrounded with the erectile tissue of the corpus spongiosum, is pierced by the ducts of *Cowper's glands*, and afterwards, in conjunction with the corpora cavernosa, enters into the formation of the *penis*.

THE PROSTATE GLAND.

The *prostate gland* is a firm glandular body, somewhat resembling a chestnut in shape and size, which supports the neck of the bladder and encloses the commencement of the urethra: it is placed in the pelvic cavity, on the deep aspect of the subpubic fascia, and rests upon the rectum. It has the form of a flattened cone with its base in contact with the bladder, and cut obliquely, so that its posterior or rectal surface is much larger than its anterior or pubic surface. It usually measures about an inch and a half across at its widest part, an inch and a quarter from its base to its apex, and nearly an inch in depth or thickness. Its ordinary weight is about six drachms.

The anterior or pubic surface of the prostate is flattened and marked with a slight longitudinal furrow; it is about half an inch or rather more from the pubic symphysis, and there, as well as the sides of the gland, is connected to the pubic arch by the reflexion of the pelvic fascia, which forms the pubo-prostatic *ligaments* or *anterior ligaments* of the bladder. The posterior or rectal surface is smooth, and is marked by a slight depression,

Fig. 668.

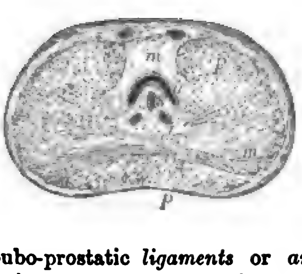


Fig. 668.—TRANSVERSE SECTION OF THE PROSTATE GLAND THROUGH THE MIDDLE.

u, the urethra, into which the eminence of the caput gallinaginis rises from below; *s*, the sinus pocularis, cut through; *d e*, the ejaculatory *ducts*; *m*, superiorly, the deep sphincter muscular fibres; *m*, lower down, intersecting muscular bands in the lateral lobes of the prostate; *p*, *p*, glandular substance.

or by two grooves, which meet in front, and correspond with the course of the seminal ducts, as well as mark the limits of the lateral lobes in this situation : it is in close apposition with the rectum, immediately in front of the bend from the middle to the lower or anal part of that viscus, where the surface and posterior border of the gland can be felt by the finger introduced into the intestine. The sides are convex and prominent, and are covered by the anterior portions of the levatores ani muscles, which pass back on either side, from the symphysis pubis and anterior ligament of the bladder, and embrace the sides of the prostate. This part of each levator ani is occasionally separated from the rest of the muscle by areolar tissue, and has been named *levator prostatæ*. The base of the gland is of considerable thickness, and is notched in the middle : its apex is turned towards the triangular ligament. As already stated, the prostate encloses the commencement of the urethra. The canal runs nearer to the upper than to the under surface of the gland, so that in general it is about three lines distant from the former and four or five from the latter ; but it frequently varies greatly in this respect. The prostatic portion of the urethra is about an inch and a quarter long, and is dilated in the middle ; it contains the verumontanum and the openings of the seminal and prostatic ducts, and will be afterwards more particularly described. The common seminal ducts, which pass forwards from the vesiculæ seminales, also traverse the lower part of the prostate, enclosed in a special canal, and open into the urethra.

Fig. 669.

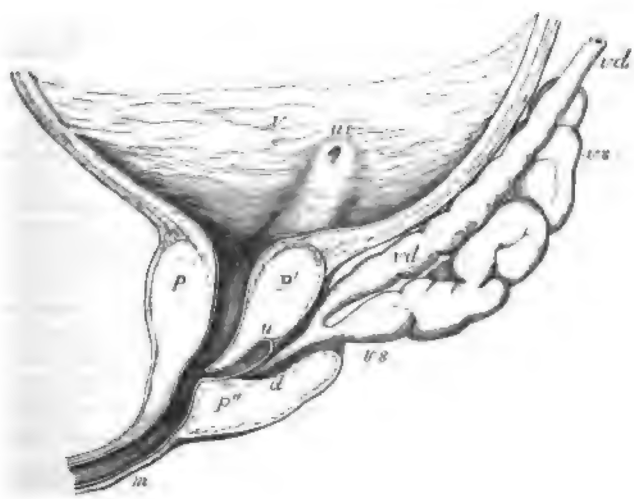


Fig. 669.—LONGITUDINAL MEDIAN SECTION OF THE LOWER PART OF THE BLADDER AND PROSTATE GLAND (after E. H. Weber).

v, inner surface of the urinary bladder ; *u r*, opening of the right ureter, from which a slight elevation runs down to the neck of the bladder ; *p*, upper part of the prostate ; *v'*, the so-called middle lobe ; *p''*, the right lateral lobe ; *u*, the utricle or sinus pocularis ; *d*, the right ejaculatory duct ; *v d*, vas deferens ; *v s*, vesicula seminalis.

This gland is usually described as consisting of three lobes, two of which, placed laterally and separated behind by the posterior notch, are of equal

size; the third, or *middle* lobe, is a smaller rounded or triangular mass, intimately connected with the other two, and fitted in between them on the under side, lying immediately beneath the neck of the bladder and the adjacent part of the urethra. This third lobe is exposed by turning down the seminal vesicles and ducts, between which and the cervix vesicæ it is placed; being in fact the part of the gland contained between and behind the grooves or fissures by which the ejaculatory ducts reach the urethra. The separation between these lobes, which is little marked in the natural state, becomes often much more apparent in disease.

Structure.—The prostate is enclosed in a dense fibrous coat, which is continuous with the recto-vesical fascia, and with the posterior layer of the triangular ligament, and is rather difficult to tear or cut. Adams describes the fibrous capsule as divisible into two layers, between which the prostatic plexus of veins is enclosed. The prostate is a highly muscular organ; its external coat contains numerous plain fibres; within the proper glandular structure, which lies somewhat superficially, there is a strong layer of circular fibres continuous posteriorly with the sphincter vesicæ. Ellis finds that these muscular fibres not only join behind with the circular fibres of the bladder, but are continuous in front with the thin layer hereafter described around the membranous part of the urethra (p. 962). According to Pettigrew, the muscular fibres of the prostate are the lower parts of figure-8 loops, which spread superiorly on the bladder. The substance of the gland is spongy and more yielding; its colour is reddish grey, or sometimes of a brownish hue. It consists of numerous small follicles or terminal vesicles opening into elongated canals, which unite into a smaller number of excretory ducts. These appear either as pores or as whitish streaks, according to the way in which they are exposed in a section. The epithelium in the vesicular terminations is thin and squamous, whilst in the canals it is columnar. The capillary blood-vessels spread out as in other similar glands on the ducts and clusters of vesicles, and the different glandular elements are united by areolar tissue, and supported by processes of the deep layer of the fibrous capsule (Adams). The ducts open by from twelve to twenty or more orifices upon the floor of the urethra, chiefly in the hollow on each side of the verumontanum (p. 963).—(Adams, Cyclop. of Anat., vol. iv., p. 147; Ellis and Pettigrew, referred to at p. 951).

Vessels and Nerves.—The prostate is supplied by branches of the vesical, hæmorrhoidal, and pudic *arteries*. Its *veins* form a plexus round the sides and base of the gland, which is highly developed in old subjects. These veins communicate in front with the dorsal vein of the penis, and behind with branches of the internal iliac vein. According to Adams, the lymphatics, like the veins, are seen ramifying between the two layers of the fibrous capsule. The *nerves* are derived from the hypogastric plexus.

Prostatic fluid.—This is mixed with the seminal fluid during emission; as obtained from the human prostate soon after death, it has a milky aspect, which is ascribed by Adams to the admixture of a large number of epithelial cells, and he thinks it probable that, as discharged during life, it is more transparent. According to the same observer, the prostatic fluid has an acid reaction, and presents, under the microscope, numerous molecules, epithelial particles both squamous and columnar, and granular nuclei about $\frac{1}{3500}$ inch in diameter. As age advances, this gland is disposed to become enlarged; and its ducts often contain small round concretions of laminated appearance, and varying from a small size up to that of a millet seed; they sometimes contain carbonate of lime, but are principally composed of animal matter, which in some of them appears to be entirely amylaceous, in others albuminous, and more frequently is of a mixed character. (Virchow's Cellular Pathology, by Chance, p. 369.)

THE PENIS.

The penis, which supports the greater part of the urethra in the male, is composed principally of an erectile tissue, arranged in masses which occupy three long and nearly cylindrical compartments. Of these, two, named *corpora cavernosa penis*, placed side by side, form the principal part of the organ, whilst the other, situated beneath the two preceding, surrounds the canal of the urethra, and is named *corpus cavernosum urethræ* or *corpus spongiosum*.

The penis is attached behind to the front of the pubes, and to the pubic arch, by what is termed the *root;* in front it ends in an enlargement named the *glans*, which is structurally continuous with the corpus spongiosum. The intermediate portion or *body* of the penis, owing to the relative position of its three compartments, has three somewhat flattened sides, and three rounded borders; its widest side is turned upwards and forwards, and is named the *dorsum*. The *glans* penis, which is slightly compressed above and below, presents at its extremity a vertical fissure, the external orifice of the urethra; its base, which is wider than the body of the penis, is hollowed out below to receive the narrowing extremities of the corpora cavernosa; its border is rounded and projecting, and is named the *corona glandis*, behind which is a constriction named the *cervix;* the posterior boundary of the glans thus marked off passes obliquely down on each side of the under surface, and ends behind the urethral opening, in a median fold of skin, named the *frænum*.

The Integuments.—The integument of the penis, which is continued from that of the pubes and scrotum, forms a simple investment as far as the neck of the glans. At this part it leaves the surface and is doubled up in a loose cylindrical fold, constituting the *prepuce* or *foreskin*. The inner layer of this fold returns to the penis behind the cervix, where it is firmly attached; and the integument becoming thus again adherent, is continued forwards over the corona and glans, as far as the orifice of the urethra, where it meets with the mucous membrane of the urethra, and behind that orifice forms the *frænum of the prepuce*. Upon the body of the penis the skin is very thin, entirely free from fat, and, excepting at the root, from hairs also; in these respects differing remarkably from that on the pubes, which is thick, covers a large cushion of fat, and, after puberty, is beset with hairs: the skin of the penis is moreover very movable and distensible, and is dark in colour. At the free margin of the prepuce the integument changes its character, and approaches to that of a mucous membrane, being red, thin and moist. Numerous sebaceous glands are collected round the cervix of the penis and corona; they are named the *glands of Tyson* (glandulæ odoriferæ). Their secretion has a peculiar odour, and was formerly supposed to constitute the white *smegma præputii*, which tends to collect beneath the foreskin; but that substance consists principally of epithelial cells cast from the opposed cuticular surfaces.

Upon the surface of the glans penis the integument again changes its character; it ceases to contain glands, but its papillæ are highly developed and extremely sensitive, and it adheres most intimately and immovably to the spongy tissue of the glans.

Beneath the skin, on the body of the penis, the ordinary superficial fascia is very distinct; it is continuous with that of the groin, and also with the dartoid tissue of the scrotum. Near the root of the organ there is in front a dense band of fibro-elastic tissue, named the *suspensory ligament*, lying amongst

the fibres of the superficial fascia; it is triangular in form; one edge is free, another is connected with the fore part of the pubic symphysis, and the third with the dorsum of the penis.

The integuments of the penis are supplied with blood by branches of the dorsal artery of the penis and external pudic; the veins join the dorsal and external pudic veins. Their nerves are entirely derived from the dorsal branches of the pudic nerves.

THE CORPORA CAVERNOSA.

The *corpora cavernosa* form the principal part of the body of the penis, and chiefly determine its form and consistence. They are two cylindrical bodies, placed side by side, flattened on their median aspects, and closely united and in part blended together along the middle line for the anterior three-fourths of their length; whilst at the back part, in contact with the symphysis pubis, they separate from each other in form of two bulging and

Fig. 670.

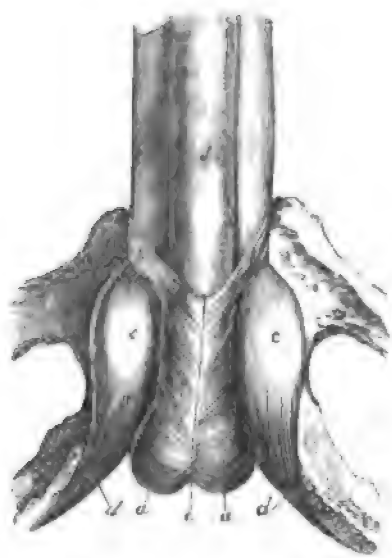


Fig. 670.—Root of the Penis attached to the Rami of the Pubes and Ischium (from Kobelt). ⅔

a, *a*, accelerator urinæ muscle covering the bulb of the spongy body of the urethra, which presents at *e*. posteriorly, a median notch; *b*, *b*, anterior slips of the muscle or bulbo-cavernosi; *c*, *c*, crura of the penis, presenting an oval dilatation, *g*, or bulb of the corpus cavernosum; *d*, *d*, erectores penis muscles; *f*, corpus spongiosum urethræ.

then tapering processes named *crura*, which extend backwards attached to the pubic and ischial rami, and invested by the erectores penis or ischio-cavernosi muscles. Immediately behind their place of union, they are slightly enlarged, so as to form what are named by Kobelt the *bulbs of the corpora cavernosa*, parts which attain a much greater proportionate development in some quadrupeds. In front, the corpora cavernosa are closely bound together into a single rounded extremity, which is covered by the glans penis and firmly connected to its base by fibrous tissue.

The under surface of the united cavernous bodies presents a longitudinal groove, in which is lodged the corpus spongiosum, containing the greatest part of the canal of the urethra. The upper or anterior surface is also marked with a slight median groove for the dorsal vein of the penis, and near the root is attached to the pubes by the suspensory-ligament.

Structure.—The median septum between the two corpora cavernosa is thick and complete behind; but farther forward it becomes thinner, and imperfectly separates their two cavities, for it presents, particularly towards the anterior extremity, numerous clefts, extending from the dorsal to the urethral edge, and admitting of a free communication between the erectile

tissue of the two sides. From the direction of these slits, the intermediate white portions of the septum are made to resemble in arrangement the teeth of a comb, and hence it is named *septum pectiniforme.*

The external fibrous investment of the cavernous structure is white and dense, from half a line to a line thick, and very strong and elastic. It is composed for the most part of longitudinal bundles of shining white fibres, with numerous well-developed elastic fibres, enclosing the two corpora cavernosa in a common covering ; but internal to this, in each compartment, is a layer of circular fibres, which enter into the formation of the septum. (J. Wilson and Ellis.)

From the interior of the fibrous envelope, and from the sides of the septum, numerous lamellæ, bands, and cords, composed of an extensible fibrous tissue, and named *trabeculæ*, pass inwards, and run through and across the cavity in all directions, thus subdividing it into a multitude of interstices, and giving the entire structure a spongy character.

Fig. 671.

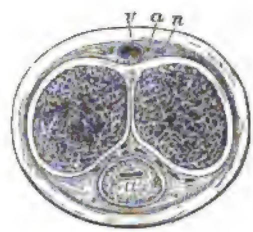


Fig. 671.—Transverse Section of the Penis in the distended state.

The integument is represented as surrounding the deeper parts ; the erectile tissue occupying the corpora cavernosa and the septum pectiniforme descending between these bodies ; *u*, placed on the section of the spongy body, marks the urethra in the form of a transverse slit ; *v*, the single dorsal vein ; *a*, the dorsal artery, and *n*, the nerve, of one side.

The trabeculæ, whether lamelliform or cord-like, are larger and stronger near the circumference than along the centre of each cavernous body, and they also become gradually thicker towards the crura. The interspaces, conversely, are larger in the middle than near the surface ; their long diameter is, in the latter situation, placed transversely to that of the penis ; and they become larger towards the forepart of the penis. They are lined by a layer of squamous epithelium. The trabeculæ contain the ordinary white fibrous tissue and fine elastic fibres, together with pale muscular fibres, arteries, and

Fig. 672.

Fig. 672.—Portion of the Erectile Tissue of the Corpus Cavernosum magnified, showing the Areolar Structure and the Vascular Distribution (from J. Müller).

a, a small artery supported by the larger trabeculæ, and branching out on all sides ; *c*, the tendril-like arterial tufts or helicine arteries of Müller ; *d*, the areolar structure formed by the finer trabeculæ.

nerves. The muscular tissue is much more abundant in the penis of some animals than in man.

The inter-trabecular spaces form a labyrinth of intercommunicating venous areolæ divided by the trabecular tissue. The spaces of the two sides communicate freely through the septum, especially in front. They return their blood partly by a series of branches which escape between the corpora cavernosa and the corpus spongiosum, and which, accompanied by veins from the latter, mount on the sides of the penis to the vena dorsalis, partly by short veins issuing at the upper surface, and immediately joining the dorsal vein, but principally by veins passing out near the root of the penis and joining the prostatic plexus and pudendal veins. According to Kobelt, there are also communications with the cutaneous veins on the abdomen.

The arteries of the corpora cavernosa are branches of the pudic artery. The proper cavernous arteries (profundæ penis), right and left, supply them chiefly; but the dorsal artery of the penis also sends twigs through the fibrous sheath, along the upper surface, especially in the fore part of the penis. Within the cavernous tissue, the numerous branches of arteries are supported by the trabeculæ, in the middle of which they run, and terminate in two modes; some of them subdividing into branches of capillary minuteness which open into the intertrabecular spaces; while others form tendril-like twigs which project into the spaces, and end in curling dilated extremities—the *helicine arteries* of J. Müller, sometimes singly and sometimes in tufts. The extremity of each curled dilatation would appear to be bound down by a small fibrous band, which according to Henle is usually solid, but is said by Kölliker to contain a capillary continuation of the blood-

Fig. 673.

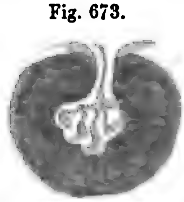


Fig. 673.—One of the Tufts containing a Helicine Artery more highly magnified (from J. Müller).

The tuft is represented as projecting into the cavity of a vein.

vessel. The helicine arteries are most abundant in the posterior part of the corpora cavernosa, and are found in the corresponding part of the corpus spongiosum also; but they have not been seen in the glans penis. They are most distinct in man, but are not constant in animals, so that, whatever may be their use, they do not appear to be essential to the process of erection.

CORPUS SPONGIOSUM.

The *corpus spongiosum urethræ* commences in front of the triangular ligament of the perineum, between the diverging crura of the corpora cavernosa, and somewhat behind their point of junction, by an enlarged and rounded extremity named the *bulb*. It extends forwards as a cylindrical, or slightly tapering body, lodged in the groove on the under side of the united cavernous bodies, as far as their blunt anterior extremity, over which it expands so as to form the glans penis already described.

The posterior bulbous extremity, or *bulb of the urethra*, varies in size in different subjects. It receives an investment from the triangular ligament in which it rests, and is embraced by the accelerator urinæ, or bulbo-cavernosus muscle. The posterior extremity of the bulb exhibits, more or

less distinctly, a subdivision into two lateral portions or lobes, separated by a slight furrow on the surface, and by a slender fibrous partition within, which extends for a short distance forwards; in early infancy this is more marked. It is above this part that the urethra, having pierced the triangular ligament, enters the bulb, surrounded obliquely by a portion of the spongy tissue, named by Kobelt the *colliculus bulbi*, from which a layer of venous erectile tissue passes back upon the membranous portion of the urethra, and also upon the prostatic part, to the neck of the bladder, lying closely beneath the mucous membrane. At first the urethra is nearer the upper than the lower part of the corpus spongiosum, but it soon gains and continues to occupy the middle of that body.

Structure.—This is essentially the same as that of the corpora cavernosa, only more delicate, or with a much less quantity of the fibrous trabecular structure. Like the corpora cavernosa, it is distended with blood during erection; but never acquires the same hardness. The outer fibrous tunic is much thinner, is less white in colour, and contains more elastic tissue; the areolæ are smaller, and directed for the most part with their long diameter corresponding to that of the penis; the trabeculæ are finer and more equal in size; and the veins form a nearly uniform plexus between them; in the glans the meshes of this plexus are smallest and most uniform. Immediately surrounding the canal of the urethra, and, again, forming part of the external coat of the spongy substance, there are plain muscular fibres, which are continuous posteriorly with those of the bladder. The helicine arteries are found in the spongy body, excepting in the part which forms the glans penis. A considerable artery derived from the internal pudic enters the bulb on each side, and supplies the greater part of the spongy body, sending branches as far as the glans penis, which, however, is chiefly supplied by the arteria dorsalis. Besides these, Kobelt describes, as constantly present, another but much smaller branch of the pudic artery, which, he says, enters the bulb on the upper surface, about an inch from its posterior extremity, and runs forwards in the corpus spongiosum to the glans. *Veins* issue from the glans and adjoining part of the spongy body, to end in the vena dorsalis penis; those of the rest of the spongy body for the most part pass out backwards through the bulb, and end in the prostatic and pudic venous plexuses: some emerge from beneath the corpora cavernosa, anastomose with their veins, and end partly in the cutaneous venous system of the penis and scrotum, and partly in the pudic and obturator veins.

The *lymphatics* of the penis form a dense network on the skin of the glans and prepuce, and also underneath the mucous lining of the urethra. They terminate chiefly in the inguinal glands. Deep-seated lymphatics are also described as issuing from the cavernous and spongy bodies, and passing under the pubic arch with the deep veins, to join the lymphatic plexuses in the pelvis.

The *nerves* of the penis are derived from the pudic nerve and from the hypogastric plexus of the sympathetic (pp. 671 and 703). They terminate by frequent division, and present indistinct traces of the so-called corpuscula tactûs; on the glans and bulb of the urethra, some fibres of the cutaneous nerves end in Pacinian bodies.

URETHRA OF THE MALE.

The *male urethra* extends from the neck of the bladder to the extremity of the penis. Its total length is about eight inches and a-half, but varies

much according to the length of the penis, and the condition of that organ. Its diameter varies at different parts of its extent, as will be stated more particularly hereafter. The tube consists of a continuous mucous mem-

Fig. 674.

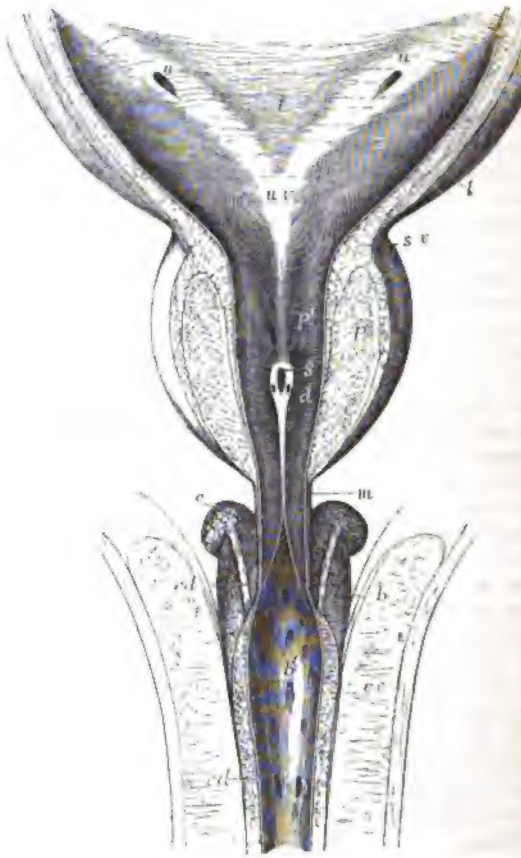


Fig. 674.—The lower part of the Bladder and the Prostatic, Membranous and Bulbous parts of the Urethra opened from above.

A portion of the wall of the bladder and the upper part of the prostate gland have been removed, the corpora cavernosa penis have been separated in the middle line and turned to the side, and the urethra has been slit up; the bulb is left entire below, and upon and behind it the glands of Cowper with their ducts have been exposed. *t*, placed in the middle of the trigon vesicæ; *u*, *u*, oblique apertures of the ureters; from these an elevation of the wall of the bladder is shown running down to *u v*, the uvula vesicæ; *l*, the longitudinal muscular fibres of the bladder passing down upon the prostate; *s v*, the circular fibres of the sphincter surrounding the neck; *p*, the glandular part of the prostate; *p'*, the prostatic portion of the urethra; from the uvula vesicæ a median ridge is seen descending to the caput gallinaginis, in which *s*, indicates the opening of the sinus pocularis, and *d*, that of one of the ductus ejaculatorii; *m*, the commencement of the membranous portion of the urethra; *b*, the bulb of the spongy body; *b'*, the bulbous part of the urethra; *c*, one of Cowper's glands; *c d*, *c d*, course and orifice of its duct lying upon the bulb, and passing forward between the spongy body and the urethra, into which along with its fellow it opens; *c c*, one of the corpora cavernosa.

brane, supported by an outer layer of submucous tissue connecting it with the several parts through which it passes. In the submucous tissue there are, throughout the whole extent of the urethra, two layers of plain muscular fibres, the innermost disposed longitudinally, and the other in a circular direction. In accordance with the name or character of those parts through which it passes, three divisions of the urethra are separately described as the *prostatic*, *membranous*, and *spongy* portions.

1. The first, or *prostatic portion*, is the part which passes through the prostate gland. It is from 12 to 15 lines in length, is the widest part of the canal, and is larger in the middle than at either end: at the neck of the bladder its diameter is nearly 4 lines, then it widens a little, so as to be rather more than 4 lines, and in old persons 5 or 6, after which it diminishes like a funnel, until, at its anterior extremity, it is smaller than at its commencement. It passes through the upper part of the prostate, above the middle lobe, so that there is more of the gland below it than above. Though enclosed in the firm glandular substance, it is more dilatable than any other part of the urethra; but immediately at the neck of the bladder, it is, as elsewhere stated, much more resistant. The transverse section of the urethra, as it lies in the prostate, is widened from side to side and somewhat folded upwards in the middle, the upper and under surface being in contact.

The lining membrane of the prostatic portion of the urethra is thrown into longitudinal folds, when no fluid is passing along it; it forms no proper valve at the neck of the bladder, unless the elevation named the uvula vesicæ is to be regarded as such. Somewhat in advance of this, and continued from it along the floor of the passage, projects a narrow median ridge, about 8 or 9 lines in length, and $1\frac{1}{2}$ line in its greatest height; this ridge gradually rises into a peak, and sinks down again at its anterior or lower end, and is formed by an elevation of the mucous membrane and subjacent tissue. This is the crest of the urethra (crista urethræ), more generally called *caput gallinaginis* and *verumontanum*. On each side of this ridge the surface is slightly depressed, so as to form a longitudinal groove, named the *prostatic sinus*, the floor of which is pierced by numerous foramina, the orifices of the prostatic ducts. Through these a viscid fluid oozes out on pressure; the ducts of the middle lobe open behind the urethral crest, and some others open before it.

Sinus pocularis.—At the fore part of the most elevated portion of the crest, and exactly in the middle line, is a recess, upon or within the margins of which are placed the slit-like openings of the common seminal, or ejaculatory ducts, one at each side. This median depression, named *sinus pocularis*, *vesica prostatica*, or *utricle*, was first described by Morgagni, and has more lately attracted renewed attention, as corresponding with the structure which in the female is developed into the uterus.

The utricle forms a cul-de-sac running upwards or backwards, from three to five lines deep, and usually about one line wide at its entrance and for some distance up, but acquiring a width of at least two lines at its upper end or fundus. The prominent walls of the narrow portion form the urethral crest, and its fundus appears to lie behind and beneath the middle lobe, and between the two lateral lobes of the prostate. Its parietes, which are distinct, and tolerably thick, are composed of fibrous tissue and mucous membrane, together with a few muscular fibres, and enclose on each side the ejaculatory duct; numerous small glands open on its inner surface. According to Kobelt and others, the caput gallinaginis contains some well-marked erectile

and muscular tissue, and it has been supposed that this eminence when distended with blood, may offer an obstacle to the passage of the semen backwards into the bladder. (E. H. Weber, Zusätze zur Lehre vom Baue und Verrichtungen der Geschlechts-Organe, 1846 ; Huschke in Sœmmerring's Anatomie, vol. v. ; Leuckart, "Vesicula Prostatica," in Cyclop. of Anat. & Phys.)

2. The *membranous portion* of the urethra comprises the part between the apex of the prostate, and the bulb of the corpus spongiosum. It measures three-quarters of an inch along its anterior, but only about half an inch on its posterior surface, in consequence of the projection upwards on it of the bulb. This is the narrowest division of the urethra. In the middle its circumference is 0·6 of an inch ; at the end 0·5. (H. Thompson.) It is placed beneath the pubic arch, the anterior concave surface being distant nearly an inch from the bone, leaving an interval, occupied by the dorsal vessels and nerves of the penis, by areolar tissue, and some muscular fibres. Its lower convex surface is turned towards the perineum, opposite to the point of meeting of the transverse muscles : it is separated by an interval from the last part of the rectum. About a line in front of the prostate, it emerges from between the anterior borders of the levatores ani, and passes through the deep layer of the subpubic fascia (p. 260) ; it is then placed between that and the anterior layer or triangular ligament through which it passes some way farther forwards, but both of these fibrous membranes are prolonged upon the canal, the one backwards and the other forwards. Between these two layers the urethra is surrounded by a little erectile tissue, by some veins, and also by the fibres of the *compressor urethræ* muscle ; beneath it, on each side, are Cowper's glands. The proper or plain muscular fibres of this portion of the urethra are continued over the outer and inner surfaces of the prostate into the muscular coat of the bladder posteriorly, and into those of the spongy portion of the urethra anteriorly. (Hancock.)

3. The *spongy portion* of the urethra, by far the longest and most variable in length and direction, includes the remainder of the canal, or that part which is surrounded by the erectile tissue of the corpus spongiosum. Its length is about six inches. The part contained within the bulb, sometimes distinguished as the *bulbous portion*, is somewhat dilated ; its circumference being equal to seven-tenths of an inch (Thompson). The succeeding portion, as far as the glans, is of uniform size, being intermediate in this respect between the bulbous and membranous portions. The cross section of its canal appears like a transverse slit. The canal of the urethra situated in the glans has, on the contrary, when seen in a cross section, the form of a vertical slit : in this part the canal is again considerably dilated, forming what is named the *fossa navicularis*, which is from four to six lines in length, and is most evident in the form of a depression on the floor of the urethra.

Lastly, at its orifice, which is a vertical fissure from two and a half to three lines in extent, and bounded by two small lips, the urethra is again contracted and reaches its narrowest dimensions. In consequence of its form, and also of the resistant nature of the tissues at its margin, this opening does not admit so large an instrument as even the membranous portion of the canal.

The Mucous Membrane of the urethra possesses a lining of stratified epithelium, of which the superficial cells are columnar, except for a short distance from the orifice, where they are squamous, and where the subjacent membrane exhibits papillæ.

The whole lining membrane of the urethra is beset with small mucous

glands and follicles, commonly named the glands of Littré, the ducts of which pass obliquely forwards through the membranes. They vary much in size and in the degree of loculation and ramification of their cavity. Besides these there are larger recesses or lacunæ, opening by oblique orifices turned forwards or down the canal. These are most abundant along the floor of the urethra, especially in its bulbous part. One large and conspicuous recess, situated on the upper surface of the fossa navicularis, is named the *lacuna magna*.

Cowper's Glands.—In the bulbous portion of the urethra, near its anterior end, are the two openings of the ducts of *Cowper's glands*. These little glands themselves are seated farther back than the bulb, beneath the fore part of the membranous portion of the urethra, between the two layers of the subpubic fascia, the anterior layer supporting them against the urethra. The arteries of the bulb pass above, and the transverse fibres of the compressor urethræ beneath these glands. They are two small firm rounded bodies, about the size of peas, and of a deep yellow colour. They are compound vesicular or racemose glands, composed of several small lobules held together by a firm investment. This latter, as well as the walls of the ducts, contains muscular tissue. The branched ducts, which commence in cellular crypts, unite to form a single excretory duct for each gland, which runs forwards with its fellow for about an inch or an inch and a half beneath the mucous membrane, and the two terminate in the floor of the bulbous part of the urethra by two minute orifices opening obliquely. These glands secrete a viscid fluid, the use of which is not known; their existence is said not to be constant, and they appear to diminish in old age: sometimes there is only one.

Occasionally there is a third glandular body in front of and between Cowper's glands; this has been named the *anterior prostate* or *anti-prostatic gland*.

The muscles in connection with the urethra and penis have been already described (p. 263).

THE TESTES, AND THEIR EXCRETORY APPARATUS.

The *testicles* or *testes*, the two glandular organs which secrete the seminal fluid, are situated in the scrotum, each being suspended by a collection of structures termed the spermatic cord.

The *spermatic cord.*—The parts which enter into this cord are the excretory duct of the testicle, named the vas deferens, the spermatic artery and veins, lymphatics, nerves, and connecting areolar tissue. Besides this, both the cord and the testis have several coverings. The structures mentioned come together to form the cord at the internal or deep abdominal ring (p. 258), and, extending through the abdominal wall obliquely downwards and towards the middle line, escape at the superficial or external abdominal ring (p. 250), whence the cord descends over the front of the pubes into the scrotum.

COVERINGS OF THE TESTIS AND CORD.

The inguinal canal.—By the term inguinal canal is understood the space occupied by the spermatic cord as it passes through the abdominal wall. It extends from the deep to the superficial abdominal ring, and is about an inch and a half in length. In the upper part of this course, the cord has placed behind it the fascia transversalis, and is covered in front by the lower fibres of the internal oblique and transversalis muscles; lower down,

it lies in front of the conjoined tendon of these muscles, the fibres of which have arched inwards over it, and its cremasteric covering is in contact anteriorly with the aponeurosis of the external oblique muscle. The inguinal canal is therefore said to be bounded posteriorly by the fascia transversalis above and the conjoined tendon below, and anteriorly by fibres of the transversalis and internal oblique muscles above, and the aponeurosis of the external oblique muscle below; while its floor is formed by the curving backwards of Poupart's ligament, and its roof by the apposition of the layers of the abdominal wall.

As it enters the inguinal canal, the cord receives a covering from the infundibuliform fascia, a thin layer continuous with the fascia transversalis, and prolonged down from the margins of the deep abdominal ring; within the canal it receives a covering from the cremaster muscle and fascia connected with it; and as it emerges from the canal there is added, superficially to this, the intercolumnar fascia prolonged from the pillars of the superficial abdominal ring.

The *scrotum.*—The *scrotum* forms a purse-like investment for the testes and part of the spermatic cords. Its condition is liable to certain variations according to the state of the health and other circumstances: thus, it is short and corrugated in robust persons and under the effects of cold, but becomes loose and pendulous in persons of weak constitution, and under the relaxing influence of heat. Its surface is marked off into two lateral halves by a slight median ridge, named the *raphe*, extending forwards to the under side of the penis, and backwards along the perineum to the margin of the anus.

Within the scrotum, the coverings of the cord and testis, as enumerated from without inwards, are the *skin*, superficial fascia and *dartos tissue* of the scrotum, the *inter-columnar fascia*, the *cremaster muscle* and cremasteric fascia, and the *infundibuliform fascia*, which is united to the cord by a layer of loose areolar tissue; lastly, the testicle has a special serous tunic, named the *tunica vaginalis*, which forms a closed sac, and covers the tunica albuginea or proper *fibrous coat* of the gland.

1. The *skin* in this situation is very thin, and is of a darker colour than elsewhere; it is generally thrown into rugæ or folds, which are more or less distinct according to the circumstances already mentioned. It is furnished with sebaceous follicles, the secretion from which has a peculiar odour, and it is covered over with thinly-scattered crisp and flattened hairs, the bulbs of which may be seen or felt through the skin when the scrotum is extended. The superficial blood-vessels are also readily distinguished through this thin integument.

2. Immediately beneath the skin of the scrotum there is found a thin layer of a peculiar loose reddish-brown tissue, endowed with contractility, and named the *dartos tunic.* This subcutaneous layer is continuous with the superficial fascia of the groin, perineum, and inner side of the thighs, but acquires a different structure, and is perfectly free from fat. The dartoid tissue is more abundant on the fore part of the scrotum than behind, and, moreover, it forms two distinct sacs, which contain the corresponding testes, and are united together along the middle line so as to establish a median partition between the two glands, named the *septum scroti*, which is adherent below to the deep surface of the raphe and reaches upwards to the root of the penis. The dartos is very vascular, and owes its contractile properties to the presence of a considerable amount of unstriped muscular tissue. Its contractility is slow in its action; it is excited by the application of cold and of

mechanical stimuli, but, apparently, not by electricity. By its action the testes are drawn up or sustained, and at the same time the skin of the scrotum is more or less corrugated.

3. The *intercolumnar* or *spermatic fascia*, a very thin and transparent but relatively firm layer, derived from the tendon of the external oblique muscle of the abdomen, is attached above to the margins of the external ring, and is prolonged downwards upon the cord and testicle. It lies at first beneath the superficial fascia, but lower down beneath the dartos, and it is intimately connected with the layer next in order.

4. The cremasteric layer is composed of scattered bundles of muscular tissue, connected together into a continuous covering by intermediate areolar membrane. The red muscular portion, which is continuous with the lower border of the internal oblique muscle of the abdomen, constitutes the *cremaster muscle* (p. 251), or *tunica erythroïdes*, and the entire covering is named the *cremasteric fascia*.

5. The *infundibuliform fascia*, continuous above with the *fascia transversalis* and the subperitoneal areolar membrane, and situated immediately beneath the cremasteric fascia, invests the cord completely, and is connected below with the posterior part of the testicle and the outer surface of its serous tunic.

On forcing air beneath the infundibuliform fascia, a quantity of loose and delicate areolar tissue is seen to connect its internal or deep surface with the vas deferens and spermatic blood-vessels, and to form lamellæ between them. This areolar tissue is continuous above with the subserous areolar tissue found beneath the peritoneum on the anterior wall of the abdomen; below, it is lost upon the back of the testicle. Together with the infundibuliform fascia just described, it forms the *fascia propria* of A. Cooper.

Lying amongst this loose areolar tissue, in front of the upper end of the cord, there is often seen a fibro-areolar band, which is connected above with the pouch of peritoneum found opposite the upper end of the inguinal canal, and which reaches downwards for a longer or shorter distance along the spermatic cord. Occasionally it may be followed as a fine cord, as far as the upper end of the tunica vaginalis; sometimes no trace of it whatever can be detected. It is the vestige of a tubular process of the peritoneum, which in the fœtus connects the tunica vaginalis with the general peritoneal membrane. The testicle is placed in the abdomen during the greater part of fœtal life; but at a period considerably prior to its escape from the abdominal cavity, a pouch of peritoneum already extends down into the scrotum. Into this pouch or *processus vaginalis peritonæi* the testicle projects from behind, supported by a duplicature of the serous membrane, named the *mesorchium*. Sooner or later after the gland has reached the scrotum, the upper part or neck of this pouch becomes contracted and finally obliterated, from the internal abdominal ring down nearly to the testicle, leaving no trace but the indistinct fibrous cord already described, whilst the lower part remains as a closed serous sac, into which the testicle depends, and which is thenceforth named the tunica vaginalis.

In the female an analogous pouch of peritoneum descends in the fœtus, for a short distance along the round ligament of the uterus, and has received the appellation of the *canal of Nuck*. Traces of it may almost always be seen in the adult.

The neck of the processus vaginalis sometimes becomes closed at intervals only, leaving a series of sacculi along the front of the cord; or a long pouch may continue open at the upper end, leading from the abdominal cavity into the inguinal canal.

In other instances, the peritoneal process remains altogether pervious, and the cavity of the tunica vaginalis is continuous with that of the peritoneum. In such a case of congenital defect, a portion of intestine or omentum may descend from the abdomen into the inguinal canal and scrotum, and constitute what is named a congenital hernia. Lastly, one or both testes may remain permanently within the abdomen, or their descent may be delayed till after puberty, when it may occasion serious disturbance. Retention of the testes in the abdomen (cryptorchismus) is, in many instances, the accompaniment of arrested development of the glandular structure; it is, however, a peculiarity which is often present without impotence.

In a few mammals, as the elephant, the testes remain permanently within the abdomen; in a much larger number, as the rodentia, they only descend at each period of rut. The complete closure of the tunica vaginalis is peculiar to man, and may be considered as connected with his adaptation to the erect posture.

6. The *tunica vaginalis.*—This tunic forms a shut sac, the opposite walls of which are in contact with each other. Like the serous membranes in general, of which it affords one of the simplest examples, it may be described as consisting of a *visceral* and a *parietal* portion. The visceral portion closely invests the greater part of the body of the testis, as well as the epididymis, between which parts it recedes in the form of a pouch (digital fossa), and lines their contiguous surfaces, and it adheres intimately to the proper fibrous tunic of the gland. Along the posterior border of the gland, where the vessels and ducts enter or pass out, the serous coat, having been reflected, is wanting.

Fig. 675.

Fig. 675.—The Left Tunica Vaginalis opened, showing the Testis, Epididymis, &c.

p, p, the cut edges of the parietal tunica vaginalis drawn aside laterally, as well as above and below; *t,* the body of the testicle; *e,* the globus major of the epididymis; *e',* the globus minor, near which, *f,* a fold of the tunica vaginalis (or ligament) passes from the body of the testis to the side; in the upper part of the figure the tunica vaginalis has been slightly dissected off at the place of its reflection on the cord to show *v d,* the vas deferens, and *g,* the organ of Giraldès; G, the three small nodules of this organ enlarged about ten times, and showing the remains of tubular structure within them.

The parietal or scrotal portion of the tunica vaginalis is more extensive than that which covers the body of the testis; it reaches upwards, sometimes for a considerable distance, upon the spermatic cord, extending somewhat higher on the inner than on the outer side. It also reaches downwards

below the testicle, which, therefore, appears to be suspended at the back of the serous sac, when this latter is distended with fluid.

VESSELS AND NERVES OF THE COVERINGS OF THE TESTIS AND CORD.

The *arteries* are derived from several sources. Thus, the two external pudic arteries (p. 437), branches of the femoral, reach the front and sides of the scrotum, supplying the integument and dartos; the superficial perineal branch of the internal pudic artery (p. 426) is distributed to the back part of the scrotum; and, lastly, more deeply seated than either of these, is a branch given from the epigastric artery, named cremasteric, because it is chiefly distributed to the cremaster muscle; it also supplies small branches to the other coverings of the cord, and its ultimate divisions anastomose with those of the other vessels. The *veins*, which, owing to the thinness of the integuments, are apparent on the surface of the scrotum, follow the course of the arteries. The *lymphatics* pass into the inguinal lymphatic glands.

The *nerves* also proceed from various sources. Thus, the ilio-inguinal, a branch of the lumbar plexus (p. 660), comes forwards through the external abdominal ring, and supplies the integuments of the scrotum; this nerve is joined also by a filament from the ilio-hypogastric branch of the same plexus: sometimes two separate cutaneous nerves come forward through the external ring. The two superficial perineal branches of the internal pudic nerve accompany the artery of the same nerve and supply the inferior and posterior parts of the scrotum. The inferior pudendal, a branch of the small sciatic nerve (p. 675), joins with the perineal nerves, and is distributed to the sides and fore part of the scrotum. Lastly, the branch of a deeper nerve, springing from the lumbar plexus, and named genito-crural (p. 661), comes into contact with the spermatic cord at the internal abdominal ring, passes with it through the inguinal canal, and supplies the fibres of the cremaster, besides sending a few filaments to the other deep coverings of the cord and testicle.

THE TESTES.

The *testes* are suspended obliquely in the scrotum by means of the cord and membranes already described: they are usually placed at unequal heights, that of the left side being lower than the other. They are of an oval form, but are slightly compressed laterally, so that they have two somewhat flattened sides or faces, an upper and a lower end, an anterior and a posterior border. They are from an inch and a half to two inches long, about an inch and a quarter from the anterior to the posterior border, and nearly an inch from side to side. The weight of each varies from three-quarters of an ounce to an ounce, and the left is often a little the larger of the two.

The front and sides of the testicle, together with the upper and the lower ends, are free, smooth, and closely invested by the tunica vaginalis. The posterior border, however, is attached to the spermatic cord, and it is here that the vessels and nerves enter or pass out. When the testis is suspended in its usual position, its upper end is directed obliquely forwards and outwards, as well as upwards, whilst the lower, which is rather smaller, has the opposite direction. It follows from this that the posterior or attached border is turned upwards and inwards, and the outer flattened face slightly backwards.

Along the outer edge of the posterior border of the gland, and resting also on the neighbouring portion of its outer face, is placed a long narrow body, the *epididymis*, which forms part of the excretory apparatus of the

testicle, and is principally composed of the convolutions of a long tortuous canal or efferent duct, to be presently described. Its upper extremity, which is enlarged and obtuse, projecting forwards on the upper end of the testis, is named the *head* of the epididymis, or *globus major;* the lower, which is more pointed, is termed the *tail,* or *globus minor;* whilst the intervening and narrower portion is named the *body.* The outer convex surface of the epididymis and the thin anterior border are free, and covered by the tunica vaginalis. The inner surface, except at the upper and lower ends, is also free, and invested by the same tunic, which here forms the digital pouch between the epididymis and the outer face of the testicle, and nearly surrounds the epididymis, except along its posterior border, which is held to the gland by a duplicature of the serous membrane, containing numerous blood-vessels. At its upper and lower extremity, the inner surface of the epididymis is attached to the testicle,—the lower end, or globus minor, by fibrous tissue and a reflection of the tunica vaginalis, the globus major also by the efferent ducts of the testicle.

At the back of the testis and epididymis, beneath the fascia propria, there is found opposite the lower two-thirds of the testis, a considerable amount of unstriped muscular tissue, the inner muscular tunic of Kölliker.

Situated on the front of the globus major, somewhat to the outer side, there are found in the majority of cases one or more short processes of the tunica vaginalis, containing fine blood-vessels. They are called *corpora Morgagni,* or *hydatids of Morgagni;* that anatomist having been the first to describe them. One of these, more dilated than the rest, and pyriform in shape, lies closely between the head of the epididymis and the testicle, and appears to be the remains of the fœtal structure, termed Müller's duct: they are without any known physiological importance.

The testis proper, exclusive of the epididymis, is enclosed in a strong capsule, the *tunica albuginea.* This is a dense unyielding fibrous membrane, of a white colour, and about half a line thick, which immediately invests the soft substance of the testicle, and preserves the form of the gland. It is composed of bundles of fibrous tissue, which interlace in every direction.

Fig. 676.

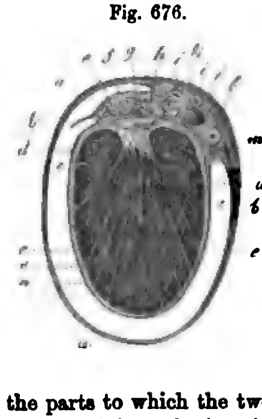


Fig. 676.—Transverse Section through the Right Testicle and the Tunica Vaginalis (from Kölliker).

a, connective tissue enveloping the parietal layer of the tunica vaginalis; *b,* this layer itself; *c,* cavity of the tunica vaginalis; *d,* reflected or visceral layer adhering to *e,* the tunica albuginea; *f,* covering of epididymis (*g*) on the right or outer side; *h,* mediastinum testis; *i,* branches of the spermatic artery; *k,* spermatic vein; *l,* vas deferens; *m,* small artery of the vas deferens; *n,* lobules of the testis; *o,* septa or processes from the mediastinum to the surface.

The surface is for the most part covered by the tunica vaginalis, except along the posterior border of the testicle, where the spermatic vessels pass through, and except also at the parts to which the two extremities of the epididymis are attached.

Viewed from the interior, the fibrous tissue of the tunica albuginea is seen to be prolonged forwards, at the posterior and upper border of the testis, for a few lines into the substance of the gland, so as to form within it an incomplete vertical septum, known as the *corpus Highmorianum,* and named

by Astley Cooper *mediastinum testis*. Projecting inwards from the back of the testis, it extends from the upper nearly to the lower end of the gland, and it is wider above than below. The firm tissue of which it is composed is traversed by a network of seminal ducts, and by the larger blood-vessels of the gland, which are lodged in channels formed in the fibrous tissue.

From the front and sides of the corpus Highmorianum numerous slender fibrous cords and imperfect septa of connective tissue are given off in radiating directions, and are attached by their outer ends to the internal surface of the tunica albuginea at different points, so as to assist in maintaining the general shape of the testicle, and enclose the several lobes into which the substance of the testis is divided. The whole internal surface of the tunica albuginea is covered by a multitude of fine blood-vessels, which are branches of the spermatic artery and veins, and are held together by a delicate areolar web. Similar delicate ramifications of vessels are seen on the various fibrous offsets of the mediastinum, upon which the blood-vessels are thus supported in the interior of the gland. This vascular network, together with its connecting areolar tissue, constitutes the *tunica vasculosa* of Astley Cooper.

The proper *glandular substance* of the testicle is a soft but consistent mass of a reddish-yellow colour, which is divided into numerous small lobes of conical form, with the larger ends turned towards the surface of the testicle, and the smaller towards the mediastinum. The number of these *lobes* (lobuli testis) has been estimated at 250 by Berres, and at upwards of 400 by Krause. They differ in size according to their position, those which occupy the middle of the gland and reach its anterior border being longer and larger than the rest. They consist almost entirely of small convoluted tubes, named *tubuli seminiferi, vascula serpentina*, in the interior of which the seminal fluid is secreted. Each lobe contains one, two, three, or even more of these con-

Fig. 677.

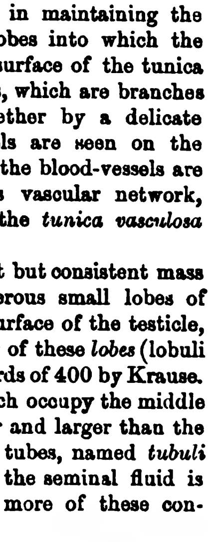


Fig. 677.—Plan of a Vertical Section of the Testicle, showing the Arrangement of the Ducts.

The true length and diameter of the ducts have been disregarded. *a*, *a*, tubuli seminiferi coiled up in the separate lobes; *b*, vasa recta; *c*, rete vasculosum; *d*, vasa efferentia ending in the coni vasculosi; *l*, *e*, *g*, convoluted canal of the epididymis; *h*, vas deferens; *f*, section of the back part of the tunica albuginea; *i*, *i*, fibrous processes running between the lobes; *s*, mediastinum.

voluted tubules, the coils of which, being but loosely held together, may be more or less successfully unravelled by careful dissection under water. Lauth estimates their mean number to be 840, and the average length two feet and a quarter. Their diameter, which is uniform throughout their whole course, is from $\frac{1}{200}$th to $\frac{1}{150}$th of an inch. They present two kinds of convolutions, each tube having a fine and regular undulation, which gives a granular appearance to the whole mass, and this undulating tube, being again thrown into complicated folds, which are compressed so as to be elongated in the direction of the lobule. The lobules are never quite distinct, for here and there tubules are always to be found passing from each to those around; and it sometimes happens that tubules which are divided by a straight plane of

contact at one part, are intimately connected at another; so that the division of the mass into lobules varies greatly in its extent, and hence the different estimates of the number of the lobules by different anatomists. The walls of the tubuli seminiferi are composed of connective tissue, lined with a basement membrane, and sometimes presenting an epithelium, composed of nucleated granular corpuscles, but, in the period of activity, filled with cells of different sizes, without regular arrangement or any lumen in the interior. In aged subjects there is much fatty matter accumulated in these cells, so that the tubes acquire a yellower colour than in early life. The walls of the tubes are sufficiently strong to bear the forcible injection of mercury, which has been commonly employed for their investigation.

The mode in which the tubes commence appears to be twofold—viz., by free closed extremities, hid within the lobules, but more frequently by anastomotic arches or loops. After an exceedingly tortuous course, they at length, in approaching the corpus Highmorianum, lose in a great measure the convoluted disposition, becoming at first slightly flexuous and then nearly straight. The separate tubuli of each lobe, and then those of adjoining lobes, unite together into larger tubes, which enter the fibrous tissue of the mediastinum and, being placed amongst the branches of the bloodvessels, form the next order of the seminal ducts.

These, which, from their comparatively straight course, are named *tubuli recti* or *vasa recta*, are upwards of twenty in number, and are from $\frac{1}{50}$th to $\frac{1}{70}$th of an inch in diameter. They pass upwards and backwards through the fibrous tissue, as already stated, and end in a close network of tubes, named by Haller the *rete vasculosum testis*, which lies in the substance of the corpus Highmorianum, along the back part of the testicle, but in front of the primary subdivisions of the spermatic blood-vessels before these enter the gland. The tubes composing the rete have very thin walls. According to Kölliker, indeed, they have none, but are mere channels in the fibrous membrane, lined with squamous epithelium. They conduct the secretion to the upper end of the testis, where they open into the vasa efferentia.

Fig. 678.

Fig. 678.—Ducts of the Testicle injected with Mercury (from Haller).

a, body of the testicle; *b*, tubuli in the interior of the gland; *c*, rete vasculosum; *d*, vasa efferentia terminating in the coni vasculosi; *e*, *f*, *g*, convoluted canal of the epididymis; *h*, vas deferens ascending from the globus minor of the epididymis.

The *vasa efferentia* are from twelve to fifteen, or sometimes twenty in number; they perforate the tunica albuginea at the upper end of the posterior border of the testicle, beneath the globus major of the epididymis, of which they may be said to form a part, and in the convoluted canal of which they ultimately terminate. On emerging from the testis, these vasa efferentia are straight, but, becoming more and more convoluted as they proceed towards the epididymis, they form a series of small conical masses, the bases of which are turned in the same direction, and which are named *coni vasculosi*. Their walls contain, besides fibrous tissue, longitudinal and transverse muscular fibres. The largest of the cones is about eight lines

long, and when unrolled, each is found to consist of a single coiled duct, varying from six to eight inches in length, and the diameter of which gradually decreases from the testis to the epididymis (Huschke). Opposite the globus major these separate efferent vessels open, at intervals which in the unravelled tube are found to be about three inches in length, into a single canal or duct, the intervening and subsequent convolutions of which constitute the epididymis itself.

Fig. 679.

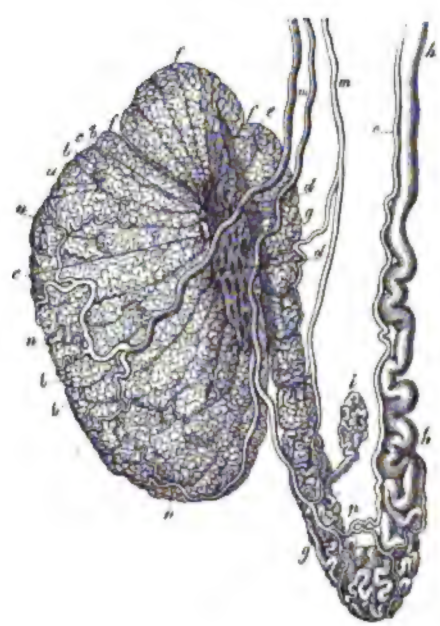


Fig. 679.—Injected Testicle, Epididymis, and Vas Deferens (from Kölliker after Arnold).

a, body of the testicle; *b*, lobules; *c*, vasa recta; *d*, rete vasculosum; *e*, vasa efferentia; *f*, coni vasculosi; *g*, epididymis; *h*, vas deferens; *i*, vas aberrans; *m*, branches of the spermatic artery passing to the testicle and epididymis; *n*, ramification in the testis; *o*, deferential artery; *p*, its union with a twig of the spermatic artery.

The *canal of the epididymis* is disposed in very numerous coils, and extends from the globus major downwards to the globus minor or tail, where, turning upwards, it is continued on as the vas deferens. When its complicated flexuosities are unrolled it is found to be twenty feet and upwards in length. The smallest windings are supported and held together by fine areolar tissue; but, besides this, numerous fibrous partitions are interposed between larger masses of the coils, which have been named the *lobes* of the epididymis, the general direction of which is across that body. The canal of the epididymis is, at its commencement, about $\frac{1}{70}$th of an inch in diameter, but diminishing as it proceeds towards the globus minor, it is about $\frac{1}{90}$th of an inch, after which it again increases in size, and becomes less tortuous as it approaches the vas deferens. Its coats, which are at first very thin, become thicker in its progress.

The vasa efferentia and the tube of the epididymis differ from the other portions of the ducts of the testis in their epithelium being ciliated. In the epididymis the cells are greatly elongated, in the vasa efferentia they are shorter; in the lower part of the epididymis the cilia disappear (Becker, corroborated in the human subject, by Kölliker).

VAS DEFERENS.

The *vas deferens*, or excretory duct of the testis, is a hard round tube, which forms the continuation upwards of the convoluted canal of the epididymis. It commences at the lower end of the epididymis, and, at first

rather tortuous, but afterwards becoming straight, it ascends upon the inner side of the epididymis, and along the back of the testicle, separated from both, however, by the blood-vessels passing to and from the gland. Continuing, then, to ascend in the spermatic cord, the vas deferens accompanies the spermatic artery, veins and nerves, as far as the internal abdominal ring. Between the testicle and the external ring its course is vertical: it lies behind the spermatic vessels, and is readily distinguished by its hard cord-like feel. Having passed obliquely upwards and outwards along the inguinal canal, and reached the inner border of the internal abdominal ring, it leaves the spermatic vessels (which extend to the lumbar region), and turns suddenly downwards and inwards into the pelvis, crossing over the external iliac vessels, and turning round the outer or iliac side of the epigastric artery. Running beneath the peritoneum, it reaches the side of the bladder, curves backwards and downwards to the under surface of that viscus, and then runs forwards to the base of the prostate gland. In its course within the pelvis, it crosses over the cord of the obliterated hypogastric artery, and to the inner side of the ureter. Beyond this point, where it ceases to be covered by the peritoneum, it is found attached to the coats of the bladder, in contact with the rectum, and gradually approaches its fellow of the opposite side. Upon the base of the bladder, the two vasa deferentia are situated between two elongated receptacles, named the seminal vesicles; and close to the base of the prostate, each vas deferens ends by joining with the duct from the corresponding seminal vesicle, which is placed on its outer side to form one of the two common seminal or ejaculatory ducts.

The vas deferens measures nearly two feet in length. In the greater part of its extent it is cylindrical or slightly compressed, and has an average diameter of about one line and a quarter; but towards its termination, beneath the bladder, it becomes enlarged and sacculated, approaching thus in character to the seminal vesicle. Previous to its junction with the duct of that vesicle, it again becomes narrowed to a fine cylindrical canal. The walls of the vas deferens are very dense and strong, measuring one-third of a line in thickness; whilst, on the other hand, the canal is comparatively fine, its diameter being only from one-fourth to one-half a line. In the sacculated portion the passage is much wider, and the walls are thinner in proportion.

Besides an external areolar investment, and an internal lining mucous membrane, the vas deferens is provided with an intermediate thick tunic, which is dense in structure, somewhat elastic, and of a deep yellowish colour. This coat consists principally of longitudinal muscular fibres, mixed with some circular ones. Huschke describes two longitudinal layers with intermediate circular fibres. The external and middle layers are thick and strong; but the internal longitudinal stratum is extremely thin, constituting not more than $\frac{1}{5}$th of the muscular coat. The vasa deferentia of the dog, cat, and rabbit were found by E. Weber to exhibit lively peristaltic contractions when stimulated by means of electricity.

The surface of the mucous membrane is pale; it is thrown into three or four fine longitudinal ridges, and, besides this, in the sacculated portion of the duct, is marked by numerous finer rugæ which enclose irregular polyhedral spaces, resembling in this the lining membrane of the vesiculæ seminales. The epithelium is of the columnar kind, not ciliated.

Vas aberrans.—This name was applied by Haller to a long narrow tube, or diverticulum, discovered by him, and almost invariably met with, which leads off from the lower part of the canal of the epididymis, or from the commencement of the vas deferens, and extends upwards in a tortuous

manner for one or two inches amongst the vessels of the spermatic cord, where it ends by a closed extremity. Its length, when it is unravelled, ranges from one inch and a half to fourteen inches; and its breadth increases towards its blind extremity. Sometimes this diverticulum is branched, and occasionally there are two or more such aberrant ducts. Its structure appears to be similar to that of the vas deferens. Its origin is probably connected with the Wolffian body of the fœtus, but the exact mode of its formation and its office are unknown. Luschka states that occasionally it does not communicate with the canal of the epididymis, but appears to be a simple serous cyst.

Organ of Giraldès.—This is a minute structure situated in the front of the cord, and in contact with the caput epididymis. It consists usually of several small irregular masses containing convoluted tubules lined with squamous epithelium, and is scarcely to be recognised until the surrounding connective tissue has been rendered transparent by reagents. Its tubules appear to be persistent elements of the Wolffian body. (Giraldès, in Bulletin de la Soc. Anat. de Paris, 1857, and in Journal de la Physiologie, 1861.)

THE SEMINAL VESICLES AND EJACULATORY DUCTS.

The *vesiculæ seminales* are two membranous receptacles, situated, one on each side, upon the base of the bladder, between it and the rectum. When distended, they form two long-shaped sacculated bodies, somewhat flattened above, where they are firmly attached to the bladder, but convex below; they are widened behind and narrow in front. Their length is usually about two inches and a half, and their greatest breadth from four to six lines; but they vary in size in different individuals, and also on opposite sides of the same subject.

Their posterior obtuse extremities are separated widely from each other, but anteriorly they converge so as to approach the two vasa deferentia, which run forwards to the prostate between them. The small triangular portion of the base of the bladder, which is marked off by the two vesiculæ semi-

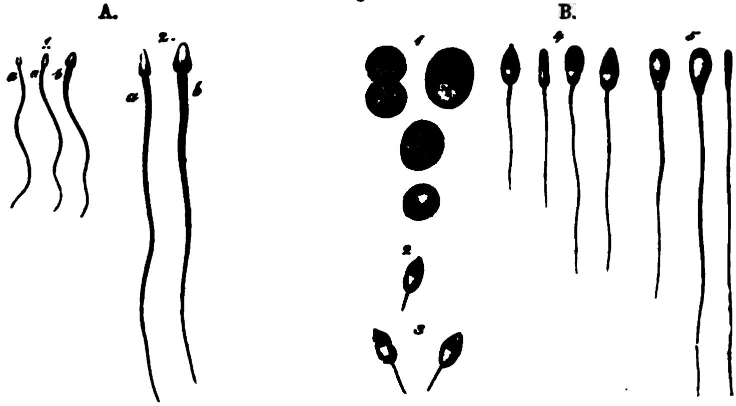
Fig. 680.

Fig. 680.—Dissection of the Base of the Bladder and Prostate Gland, showing the Vesiculæ Seminales and Vasa Deferentia (from Haller).

a′, lower surface of the bladder at the place of reflection of the peritoneum; *b*, the part above covered by the peritoneum; *i*, left vas deferens, ending in *e*, the ejaculatory duct; *s*, left vesicula seminalis joining the same duct; *s*, *s*, the right vas deferens and right vesicula seminalis, which has been unravelled; *p*, under side of the prostate gland; *m*, part of the urethra; *u*, *u*, the ureters, the right one turned aside.

The *seminal granules* are rounded colourless corpuscles, having a granular aspect. They average about $\frac{1}{4000}$th of an inch in diameter, and may be allied to mucous corpuscles.

Fig. 681.



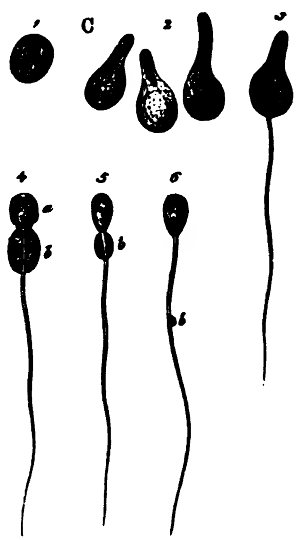


Fig. 681 A.—Spermatic Filaments from the Human Vas Deferens (from Kölliker).

1, magnified 350 diameters; 2, magnified 800 diameters; *a*, from the side; *b*, from above.

Fig. 681 B.—Spermatic Cells and Spermatozoa of the Bull undergoing development (from Kölliker). $\frac{450}{1}$

1, spermatic cells with one or two nuclei, one of them clear; 2, 3, free nuclei with spermatic filaments forming; 4, the filaments elongated and the body widened; 5, filaments nearly fully developed.

Fig. 681 C.—Escape of the Spermatozoa from their Cells in the same Animal.

1, spermatic cell containing the spermatozoon coiled up within it; 2, the cells elongated by the partial uncoiling of the spermatic filament; 3, a cell from which the filament has in part become free; 4, the same with the body also partially free; 5, spermatozoon from the epididymis with vestiges of the cell adherent; 6, spermatozoon from the vas deferens, showing the small enlargement, *b*, on the filament.

The *spermatozoa* are peculiar particles, which, during life and for some hours after being removed from the testicle, perform rapid vibratory or lashing movements. Each consists of a flattened oval part or so-called body, and of a long slender filiform tail. The body is about $\frac{1}{6000}$th of an inch in width, and the entire spermatozoon is from $\frac{1}{800}$th to $\frac{1}{400}$th of an inch in length. The body often contains a minute spot, and, at its junction with the narrow filament or tail, there is frequently a slight projecting fringe or collar. The spermatozoa are developed like nuclei in the interior of the spermatic cells, the cells subsequently becoming enlarged into transparent vesicular bodies of considerable size, in which one or several spermatozoa may be seen. Sometimes a group of cells, each containing a single spermatozoon, is seen enclosed within a parent cell. The spermatozoa are not normally found free until they reach the rete testis.

(Wagner and Leuckart, Article "Semen" in Cyclop. of Anat. and Phys.; Kölliker in Handbuch.)

ORGANS OF GENERATION IN THE FEMALE.

The generative organs in the female consist of the ovaries, uterus, and Fallopian tubes, which are named the *internal*, and the vagina and vulva, named the *external* organs of generation.

THE VULVA.

The *vulva*, or *pudendum*, is a general term, which includes all the parts perceptible externally, viz., the mons Veneris, the labia, the hymen or carunculæ, the clitoris, and the nymphæ. The urethra also may be described in connection with these parts.

The integument on the fore part of the pubic symphysis, elevated by a quantity of areolar and adipose substance deposited beneath it, and covered with hair, is termed the *mons Veneris*. The *labia pudendi* (labia externa v. majora) extend downwards and backwards from the mons, gradually becoming thinner as they descend. They form two rounded folds of integument so placed as to leave an elliptic interval (*rima*) between them, the outer surface of each being continuous with the skin, and covered with scattered hairs, whilst the inner is lined by the commencement of the genito-urinary mucous membrane. Between the skin and mucous membrane there is found, besides fat, vessels, nerves, and glands, some tissue resembling that of the dartos in the scrotum of the male. The labia majora unite beneath the mons and also in front of the perineum, the two points of union being called commissures. The posterior or inferior commissure is about an inch distant from the margin of the anus, and this interval is named the perineum. Immediately within the posterior commissure, the labia are connected by a slight transverse fold (*frænulum pudendi*), which has also received the name of *fourchette*, and is frequently torn in the first parturition. The space between it and the commissure has been called *fossa navicularis*.

Beneath the anterior commissure, and concealed between the labia, is the *clitoris*, a small elongated body corresponding in conformation and structure to a diminutive penis, but differing in having no corpus spongiosum nor urethra connected with it below. It consists of two *corpora cavernosa*, which are attached by *crura* to the rami of the ischium and pubes, and are united together by their flattened inner surfaces which form an incomplete pectiniform septum. The body of the clitoris, which is about an inch and a half long, but is hidden beneath the mucous membrane, is surmounted by a small *glans*, consisting of spongy erectile tissue. The glans is imperforate, but highly sensitive, and covered with a membranous fold, analogous to the prepuce. There is a small suspensory ligament, like that of the penis; and the two ischio-cavernous muscles, named in the female *erectores clitoridis*, have the same connections as in the male, being inserted into the crura of the corpora cavernosa.

From the glans and preputial covering of the clitoris two narrow pendulous folds of mucous membrane pass backwards for about an inch and a half, one on each side of the entrance to the vagina. These are the *nymphæ* (labia interna v. minora). Their inner surface is continuous with that of the vagina; the external insensibly passes into that of the labia majora. They contain vessels between the laminæ of tegumentary membrane, but, according to Kobelt, no erectile plexus; indeed they would seem to correspond to the cutaneous covering of the male urethra (supposed to be split

open), whilst the erectile structure corresponding to the bulb and spongy body (in two separate right and left halves) lies deeper, as will be presently explained. (Kobelt, Die männlichen und weiblichen Wollustorgane, 1844.)

Fig. 681.*

Fig. 681.*—LATERAL VIEW OF THE ERECTILE STRUCTURES OF THE EXTERNAL ORGANS IN THE FEMALE (from Kobelt). §

The blood-vessels have been injected, and the skin and mucous membrane have been removed; *a*, bulbus vestibuli; *c*, plexus of veins named pars intermedia; *e*, glans clitoridis; *f*, body of the clitoris; *h*, dorsal vein; *l*, right crus clitoridis; *m*, vestibule; *n*, right gland of Bartholin.

Between the nymphæ is the angular interval called the *vestibule*, in which is situated the circular *orifice* of the *urethra*, or *meatus urinarius*, about an inch below the clitoris and just above the entrance to the vagina. The membrane which surrounds this orifice is rather prominent in most instances, so as readily to indicate its situation.

Immediately below the orifice of the urethra is the *entrance* to the *vagina*, which, in the virgin, is usually more or less narrowed by the *hymen*. This is a thin duplicature of the mucous membrane, placed at the entrance to the vagina; its form varies very considerably in different persons, but is most frequently semilunar, the concave margin being directed forwards towards the pubes. Sometimes it is circular, and is perforated only by a small round orifice, placed usually a little above the centre; and occasionally it is cribriform, or pierced with several small apertures; and it may in rare instances completely close the vagina, constituting "imperforate hymen." On the other hand, it is often reduced to a mere fringe, or it may be entirely absent. After its rupture, some small rounded elevations remain, called *carunculæ myrtiformes*.

The *mucous membrane* may be traced inwards from the borders of the labia majora, where it is continuous with the skin: it forms a fold over the vascular tissue of the nymphæ, and is then prolonged into the urethra and vagina. It is smooth, reddish in colour, is covered by a scaly epithelium, and is provided with a considerable number of mucous crypts and follicles and with glands which secrete an unctuous and odorous substance. The mucous crypts and follicles are especially distinct on the inner surface of the nymphæ, and near the orifice of the urethra. The sebaceous glands are found beneath the prepuce, and upon the labia majora and outer surface of the nymphæ.

The *glands of Bartholin* (or of Duverney), corresponding to Cowper's glands in the male, are two reddish yellow round or oval bodies, about the size of a large pea or small bean, lodged one on each side of the commencement of the vagina, between it and the erectores clitoridis muscles, beneath the superficial perineal fascia, and in front of the transverse muscles. Their ducts, which are long and single, run forward and

open on the inner aspect of the nymphæ, outside the hymen or carunculæ myrtiformes.

Erectile tissue—All the parts of the vulva are supplied abundantly with blood-vessels, and in certain situations there are masses composed of venous plexuses, or erectile tissue, corresponding to those found in the male. Besides the corpora cavernosa and glans clitoridis, already referred to, there

Fig. 682.

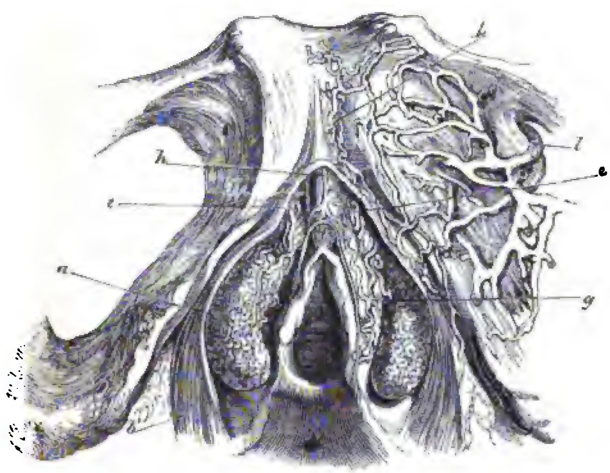


Fig. 682.—Front View of the Erectile Structures of the External Organs in the Female (from Kobelt). ⅔

a, bulbus vestibuli; *b*, sphincter vaginæ muscle; *e*, *e*, venous plexus or pars intermedia; *f*, glans clitoridis; *g*, connecting veins; *h*, dorsal vein of the clitoris; *k*, veins passing beneath the pubes; *l*, the obturator vein.

are two large leech-shaped masses, the *bulbi vestibuli*, about an inch long, consisting of a network of veins, enclosed in a fibrous membrane, and lying one on each side of the vestibule, a little behind the nymphæ. They are rather pointed at their upper extremities, and rounded below: they are suspended, as it were, to the crura of the clitoris and the rami of the pubes, covered internally by the mucous membrane, and embraced on the outer side by the fibres of the constrictor vaginæ muscle. They are together equivalent to the bulb of the urethra in the male, which it will be remembered presents traces of a median division. In front of the bipartite bulb of the vestibule is a smaller plexus on each side, the vessels of which are directly continuous with those of the bulbus vestibuli behind, and of the glans clitoridis before. This is the *pars intermedia* of Kobelt, and is regarded by him as corresponding with the part of the male corpus spongiosum urethræ which is in front of the bulb: it receives large veins coming direct from the nymphæ.

Vessels.—The outermost parts of the vulva are supplied by the superficial pudendal arteries; the deeper parts and all the erectile tissues receive branches from the internal pudic arteries, as in the male. The veins also in a great measure correspond; there is a vena dorsalis clitoridis, receiving branches from the glans and other parts as in the male; the veins of the bulbus vestibuli pass backwards into the vaginal plexuses, and are connected also with the obturator veins; above they communicate with the

veins of the pars intermedia, those of the corpora cavernosa and the glans of the clitoris, and also with the vena dorsalis. The lymphatics accompany the blood-vessels.

Nerves.—Besides sympathetic branches, which descend along the arteries, especially for the erectile tissues, there are other nerves proceeding from the lumbar and sacral plexuses; those from the former being the branches of the genito-crural (p. 660), and those from the latter of the inferior pudendal and internal pudic nerves (p. 675), which last sends comparatively large branches to the clitoris. The mode of termination is not known with certainty; tactile corpuscles have been seen in the human clitoris, and Pacinian bodies in that of some animals.

THE FEMALE URETHRA.

The *female urethra*, as compared with that of the other sex, is short, representing only the upper half of the prostatic part of the male passage. It is about an inch and a-half in length, and is wide and capable of great distension; its ordinary diameter is about three or four lines, but it enlarges towards its vesical orifice. The direction of this canal is downwards and forwards, and it is slightly curved and concave upwards. It lies imbedded in the upper or rather the anterior wall of the vagina, from which it cannot be separated.

The external orifice, or *meatus urinarius*, opens in the vulva, beneath the symphysis pubis, nearly an inch below and behind the clitoris, between the nymphæ, and immediately above the entrance to the vagina. From its orifice, which is its narrowest part, the canal passes upwards and backwards between the crura of the clitoris and behind the pubes, gradually enlarging into a funnel-shaped opening as it approaches and joins the neck of the bladder. There is also a dilatation in the floor of the canal, just within the meatus.

The mucous membrane is whitish, except near the orifice; it is raised into longitudinal plicæ, which are not entirely obliterated by distension, especially one which is particularly marked on the lower or posterior surface of the urethra. Near the bladder the membrane is soft and pulpy, with many tubular mucous glands. Lower down these increase in size and lie in groups, between the longitudinal folds, and immediately within and around the orifice, the lips of which are elevated, are several larger and wider crypts.

The lining membrane is covered with a scaly epithelium, but near the bladder the particles become spheroidal. The submucous areolar tissue contains elastic fibres. Outside this there is a highly vascular structure, in which are many large veins. Between the anterior and posterior layers of the triangular ligament, the female urethra is embraced by the fibres of the compressor urethræ muscle.

The *vessels* and *nerves* of the female urethra are very numerous, and are derived from the same sources as those of the vagina.

THE VAGINA.

The *vagina* is a membranous and dilatable tube, extending from the vulva to the uterus, the neck of which is embraced by it. It rests below and behind on the rectum, supports the bladder and urethra in front, and is enclosed between the levatores ani muscles at the sides. Its direction is curved backwards and upwards: its axis corresponding below with that of the outlet of the pelvis, and higher up with that of the pelvic cavity. In consequence of being thus curved, its length is greater along the posterior than along the anterior wall, being in the latter situation about four inches,

while in the former it amounts to five or six. Each end of the vagina is somewhat narrower than the middle part: the lower, which is continuous with the vulva, is the narrowest part, and has its long diameter from before

Fig. 683.

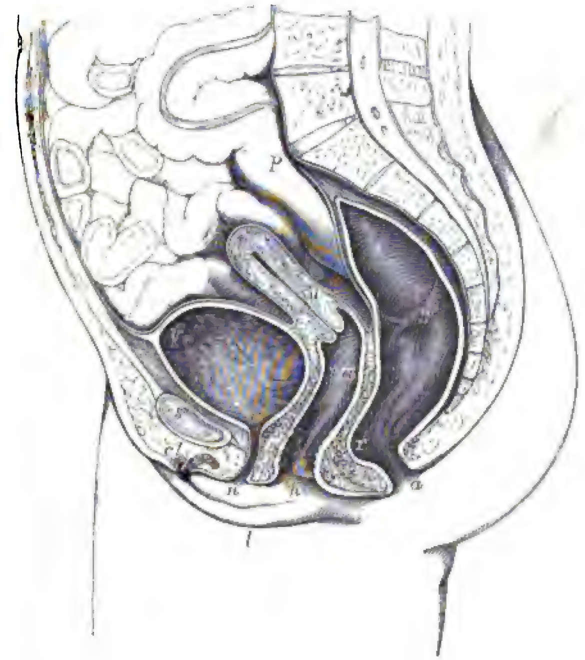


Fig. 683.—Sectional View of the Viscera of the Female Pelvis (after Houston and from nature). ½

p, promontory of the sacrum; *s*, symphysis of the pubes; *v*, the upper part of the urinary bladder; *v'*, the neck; *v'*, *n*, the urethra; *u*, the uterus; *va*, the vagina; *r*, the point of union of the middle and lower parts of the rectum: *r'*, the fold between the middle and upper parts of the rectum; *a*, the anus; *l*, the right labium; *n*, the right nympha; *h*, the hymen; *cl*, the divided clitoris with the prepuce. The pelvic viscera, having been distended and hardened with alcohol previous to making the section, appear somewhat larger than natural.

backwards; the middle part is widest from side to side, being flattened from before backwards, so that its anterior and posterior walls are ordinarily in contact with each other; at its upper end it is rounded, and expands to receive the vaginal portion of the neck of the uterus, which is embraced by it at some distance from the os uteri. The vagina reaches higher up on the cervix uteri behind than in front, so that the uterus appears, as it were, to be let into its anterior wall.

On the *inner surface* of the vagina, along the anterior and the posterior walls, a slightly elevated ridge extends from the lower end upwards along the middle line, similar to the raphe in other situations: these ridges are named the *columns* of the vagina, or *columnæ rugarum.* Numerous dentated transverse ridges, called *rugæ*, will also be observed, particularly in persons who have not borne children, running at right angles from the columns. These columns and rugæ are most evident near the entrance of

the vagina and on the anterior surface, and gradually become less marked, and disappear towards its upper end.

Structure and connections.—The walls of the vagina are thickest in front, in the vicinity of the urethra, which indeed may be said to be imbedded in the anterior wall of the vaginal passage; in other situations they are thinner. The vagina is firmly connected by areolar tissue to the neck of the bladder, and only loosely to the rectum and levatores ani muscles; at the upper end, for about a fourth part of its length, it receives a covering behind from the peritoneum, which descends in the form of a cul-de-sac thus far between the vagina and the rectum.

Externally the vagina presents a coat of dense areolar tissue, and beneath this its walls are composed of unstriped muscle, which is not distinctly separable into strata, but is composed chiefly of fibres internally circular and externally longitudinal. Round the tube a layer of loose erectile tissue is found, which is most marked at the lower part.

At its lower end, the vagina is embraced by muscular fibres, which constitute the *sphincter vaginæ*, already described (p. 266).

The mucous membrane, besides the columns and rugæ, is provided with conical and filiform papillæ, numerous muciparous glands and follicles, especially in its upper smoother portion and round the cervix uteri. This membrane, which is continuous with that of the uterus, is covered with a squamous epithelium.

The vagina is largely supplied with vessels and nerves. The arteries are derived from branches of the internal iliac, viz., the vaginal, internal pudic, vesical, and uterine (pp. 422, 428). The veins correspond; but they first surround the vagina with numerous branches, and form at each side a plexus named the *vaginal* plexus. The *nerves* are derived from the hypogastric plexus of the sympathetic, and from the fourth sacral and pudic nerves of the spinal system; the former are traceable to the erectile tissue (p. 704).

THE UTERUS.

The *uterus*, *womb*, or *matrix*, is a hollow organ, with very thick walls, which is intended to receive the ovum, retain and support it during the development of the fœtus, and expel it at the time of parturition. The ova, discharged from the ovaries, reach the uterus by the Fallopian tubes, which open, one at each side, into the upper part of that organ. During pregnancy, the uterus undergoes a great enlargement in size and capacity, as well as other important changes. In the fully-developed virgin condition, which is that to which the following description applies, it is a pear-shaped body, flattened from before backwards, situated in the cavity of the pelvis, between the bladder and rectum, with its lower extremity projecting into the upper end of the vagina. It does not reach above the brim of the pelvis. Its upper end is turned upwards and forwards, whilst the lower is in the opposite direction; so that its position corresponds with that of the axis of the inlet of the pelvis, and forms an angle or curve with the axis of the vagina, which corresponds with that of the outlet of the cavity. The uterus projects, as it were, upwards into a fold of the peritoneum, by which it is covered behind and above, and also in front, except for a short distance towards the lower end, where it is connected with the base of the bladder. Its free surface is in contact with the other pelvic viscera, some convolutions of the small intestine usually lying upon and behind it. From its two sides the peritoneum is reflected in the form of a broad

duplicature, named the ligamentum latum, which, together with the parts contained within it, will be presently described.

Fig. 684.

Fig. 684.—Anterior View of the Uterus and its Appendages. ½

a, fundus ; *b*, body ; *c*, cervix ; *e*, front of the upper part of the vagina ; *n*, *n*, round ligaments ; *r*, *r*, broad ligaments ; *s*, *s*, Fallopian tubes ; *t*, fimbriated extremity ; *u*, ostium abdominale ; the position of the ovaries is indicated through the broad ligaments, and the cut edge of the peritoneum is shown along the side of the broad ligaments and across the front of the uterus.

The average dimensions of the uterus are about three inches in length, two in breadth at his upper and wider part, and nearly an inch in thickness : its weight is from seven to twelve drachms. It is usually described as possessing a fundus, body, and neck.

The *fundus* is the broad upper end of the body, and projects convexly upwards from between the points of attachment of the Fallopian tubes. During gestation, its convexity is greatly increased, and it surrounds a large part of the uterine cavity. The *body* gradually narrows as it extends from the fundus to the neck ; its sides are straight ; its anterior and posterior surfaces are both somewhat convex, but the latter more so than the former. At the points of union of the sides with the rounded superior border or fundus, are two projecting angles, with which the Fallopian tubes are connected, the round ligaments being attached a little before, and the ovarian ligaments behind and beneath them : these three parts are all included in the duplicature of the broad ligaments. The *neck*, or *cervix uteri*, narrower and more rounded than the rest of the organ, is from six to eight lines long ; it is continuous above with the body, and, becoming somewhat smaller towards its lower extremity, projects into the upper end of the tube of the vagina, which is united all round with the substance of the uterus, but extends upwards to a greater distance behind than in front. The projecting portion is sometimes named the *vaginal part*. The lower end of the uterus presents a transverse aperture, by which its cavity opens into the vagina ; this is named variously *os uteri*, *os uteri externum*, and (from some supposed likeness to the mouth of the tench fish) *os tincæ*. It is bounded by two thick lips, the posterior of which is the thinner and longer of the two, while the anterior, although projecting less

from its vaginal attachment, is lower in position, and, when the tube is closed, rests on the posterior wall of the vagina. These borders or lips are generally smooth, but, after parturition, they frequently become irregular, and are sometimes fissured or cleft.

Fig. 685.

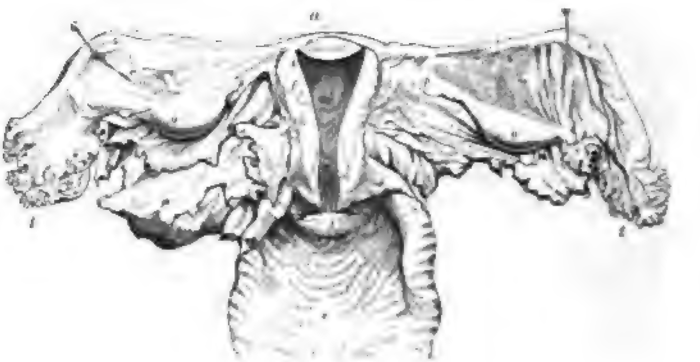


Fig. 685.—Posterior View of the Uterus and its Appendages.

The cavity of the uterus has been opened by the removal of the posterior wall, and the upper part of the vagina has been laid open; *a*, fundus; *b*, body; *c*, cervix; *d*, on the anterior lip of the os uteri externum; *e*, the interior of the vagina; *f*, section of the walls of the uterus; *i*, opening of the Fallopian tube; *o*, ovary; *p*, ligament of the ovary; *r*, broad ligament; *s*, Fallopian tube; *t*, its fimbriated extremity.

Owing to the great thickness of its walls, the *cavity* of the uterus is very small in proportion to the size of the organ. The part within the body of the organ is triangular, and flattened from before backwards, so that its anterior and posterior walls touch each other. The base of the triangle is directed upwards, and is curvilinear, the convexity being turned towards the interior of the uterus. This form is owing to the prolongation of the cavity through the substance of the organ towards its two superior angles, where two minute foramina lead into the Fallopian tubes. At the point where the body is continuous below with the neck, the cavity is slightly constricted, and thus forms what is sometimes named the *internal orifice* (*os uteri internum, isthmus vel ostium uteri*); it is often smaller than the os externum, and is a circular opening. That portion of the cavity which is within the *neck*, resembles a tube slightly flattened before and behind; it is somewhat dilated in the middle, and opens inferiorly into the vagina by the os tincæ. Its inner surface is marked by two longitudinal ridges or columns, which run, one on the anterior, the other on the posterior wall, and from both of which rugæ are directed obliquely upwards on each side, so as to present an appearance which has been named *arbor vitæ uterinus*, also *palmæ plicatæ*: this structure is most strongly marked anteriorly.

Structure.—The walls of the uterus consist of an external serous covering, an internal mucous membrane, and an intermediate proper tissue. The *peritoneal* layer covers the fundus and body, except at the sides and for about half an inch of the lower part of the body in front, which is attached to the base of the bladder.

The *proper tissue* of the uterus constitutes much the greater part of its walls, which are thickest opposite the middle of the body and fundus,

and are thinnest at the entrances of the Fallopian tubes. The tissue is very dense; it is composed of bundles of muscular fibres of the plain variety, of small size in the unimpregnated uterus, interlacing with each other, but disposed in bands and layers, intermixed with much fibro-areolar tissue, a large number of blood-vessels and lymphatics, and some nerves. The areolar tissue is more abundant near the outer surface. The arrangement of the muscular fibres is best studied in the uterus at the full period of gestation, in which the bands and layers formed by them become augmented in size, and much more distinctly developed. They may be referred to three sets or orders, viz., external, internal, and intermediate. Those of the *external* set are arranged partly in a thin superficial sheet, immediately beneath the peritoneum, and partly in bands and incomplete strata, situated more deeply. A large share of these fibres arch transversely over the fundus and adjoining part of the body of the organ, and converge at either side towards the commencement of the round ligaments, along which they are prolonged to the groin. Others pass off in like manner to the Fallopian tubes, and strong transverse bands from the anterior and posterior surfaces are extended into the ovarian ligaments. A considerable number of thinly-scattered fibres also pass at each side into the duplicature of the broad ligament, and others are described as running back from the cervix of the uterus into the recto-uterine folds or plicæ semilunares. The fibres of the subperitoneal layer are much mixed with areolar tissue, especially about the middle of the anterior and posterior surfaces of the uterus, in which situation many of the superficial fibres appear to have as it were a median attachment from which they diverge. The fibres on the *inner* surface of the uterus are disposed with comparative regularity in its upper part, being arranged there in numerous concentric rings round the openings of the two Fallopian tubes, the outermost and largest circles of the two series meeting from opposite sides in the middle of the uterus. Towards the cervix the internal fibres run more transversely; elsewhere they take various directions. The *intermediate* fibres, between the external and internal set, pass in bands among the blood-vessels, following less regular courses.

The *mucous membrane* which lines the uterus is thin and closely adherent to the subjacent substance, especially in the body of the organ. It is continued from the vagina, and into the Fallopian tubes. Between the rugæ of the cervix, already described, it is provided with numerous mucous follicles and glands. There are also occasionally found in the same situation certain small transparent vesicular bodies, which, from an erroneous opinion as to their nature, were named the *ovula Nabothi*. They appear to be closed and obstructed mucous follicles, distended with a clear viscous fluid. In the inferior third or half of the cervix, the mucous membrane presents papillæ covered with ciliated epithelium.

In the body of the uterus the mucous membrane is thin, smooth, soft, and of a reddish-white colour. When viewed with a magnifying lens, it is found to be marked with minute dots, which are the orifices of numerous simple tubular glands, somewhat like those of the intestine. Some of these tubular glands are branched, and others are slightly twisted into a coil. These glands can be distinctly seen in the unimpregnated and in the virgin uterus, but they become enlarged and more conspicuous after impregnation (fig. 686). The epithelium is columnar and ciliated.

Ligaments of the uterus.—Where the peritoneum is reflected from the uterus to the bladder in front, and to the rectum behind, it forms, in each

position, two semilunar folds, which are sometimes called respectively, the *anterior* and the *posterior ligaments* of the uterus. The former are also named the *vesico-uterine*, and the latter, which are more marked, the *recto-uterine folds*.

Fig. 686.

A. B

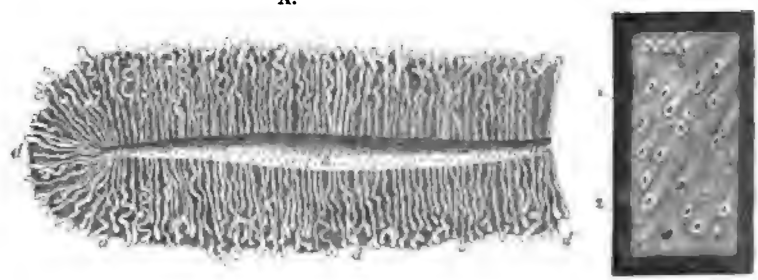


Fig. 686, A.—SECTION OF THE GLANDULAR STRUCTURE OF THE HUMAN UTERUS AT THE COMMENCEMENT OF PREGNANCY (from E. H. Weber)

a, part of the cavity of the uterus showing the orifices of the glands; *d*, a number of the tubular glands, some of which are simple, others slightly convoluted and divided at the extremities.

Fig. 686, B.—SMALL PORTION OF THE UTERINE MUCOUS MEMBRANE AFTER RECENT IMPREGNATION, SEEN FROM THE INNER SURFACE (from Sharpey).

The specimen is represented as viewed upon a dark ground, and shows the orifices of the uterine glands, in most of which, as at 1, the epithelium remains, and in some, as at 2, it has been lost.

The *broad ligaments* (ligamenta lata) are formed on each side by a fold of the peritoneum, which is directed laterally outwards from the anterior and posterior surfaces of the uterus, to be connected with the sides of the pelvic cavity. Between the two layers of the serous membrane are placed, first, the Fallopian tube, which, as will be more particularly described, runs along the upper margin of the broad ligament; secondly, the round ligament, which is in front; thirdly, the ovary and its ligament, which lie in a special offshoot of the ligamentum latum, behind; and, lastly, blood-vessels, lymphatics, and nerves, with some scattered fibres from the superficial muscular layer of the uterus. The *ligament of the ovary* is merely a dense fibro-areolar cord, containing also, according to some authorities, uterine muscular fibres, and measuring about an inch and a half in length, which extends from the inner end of the ovary to the upper angle of the uterus, immediately behind and below the point of attachment of the Fallopian tube; it causes a slight elevation of the posterior layer of the serous membrane, and, together with the ovary itself, forms the lower limit of a triangular portion of the broad ligament, which has been named the *ala vespertilionis* or bat's wing.

The *round ligaments* are two cord-like bundles of fibres, about four or five inches in length, attached to the upper angles of the uterus, one on either side (ligamentum teres uteri), immediately in front of the Fallopian tube. From this po nt each ligament proceeds upwards, outwards, and forwards, to gain the internal inguinal ring; and after having passed, like the spermatic cord in the male, through the inguinal canal, reaches the fore part of the pubic symphysis, where its fibres expand and become united with the

substance of the mons Veneris. Besides areolar tissue and vessels, the round ligaments contain plain muscular fibres, like those of the uterus, from which, indeed, they are prolonged. Each ligament also receives a covering from the peritoneum, which, in the young subject, is prolonged under the form of a tubular process for some distance along the inguinal canal: this, which resembles the processus vaginalis originally existing in the same situation in the male, is named the canal of Nuck: it is generally obliterated afterwards, but is sometimes found even in advanced life.

Blood-vessels and Nerves.—The *arteries of the uterus* are four in number, viz., the right and left *ovarian* (which correspond to the spermatic of the male) and the two *uterine*. Their origin, as well as the mode in which they reach the uterus and ovaries, has been already described (pp. 414, 422). They are remarkable for their frequent anastomoses, and also for their singularly tortuous course; within the substance of the uterus they seem to be placed in little channels or canals. The *veins* correspond with the arteries; they are very large, and form the uterine plexuses, and their thin walls are in immediate contact with the uterine tissue. The course of the lymphatics is described at p. 495; they are very large and abundant in the gravid uterus. The *nerves* have been fully described at p. 704. They are derived from the inferior hypogastric plexuses, the spermatic plexuses, and the third and fourth sacral nerves.

The *changes which take place in the uterus* from age, menstruation, and gestation, and the characters presented by this organ after it has once performed the latter function, can only be very generally indicated here.

For some time after *menstruation* first commences, the uterus becomes rounder and slightly enlarged at each period, its os externum becomes more rounded, and its lips swollen; subsequently these periodical alterations are not so marked. The organ itself, however, always becomes more turgid with blood, and the mucous membrane appears darker, softened, and thickened.

In *gestation* more extensive alterations ensue, which necessarily affect the size, shape, and position of the organ, the thickness and amount of substance in its walls, the dimensions and form of its cavity, and the character of its cervix and of its os externum and os internum. Its weight increases from about one ounce to one pound and a half or even three pounds. Its colour becomes darker, its tissue less dense, its muscular bundles more evident, and the fibres more developed. The principal increase is in the muscular tissue, and this increase takes place not only by the enlargement of already existing elements, the fibre cells becoming enlarged from seven to eleven times in length, and from two to five times in breadth (Kölliker), but also by new formation. The former process is general; the latter occurs mainly in the innermost layers, and continues until the sixth month of pregnancy, when new formation ceases. The round ligaments become enlarged, and their muscular structure more marked; the broad ligaments are encroached upon by the intrusion of the growing uterus between their layers. The mucous membrane and the glands of the body of the uterus become the seat of peculiar changes, which lead to the formation of the decidual membrane; whilst the membrane of the cervix loses its columns and rugæ. The blood-vessels and lymphatics are greatly enlarged, and it is observed that the arteries become exceedingly tortuous as they ramify upon the organ. The condition of the nerves in the gravid uterus has been previously fully referred to (p. 704).

After parturition, the uterus again diminishes, its enlarged muscular fibres undergoing oleaginous degeneration and becoming subsequently absorbed, while a new set of minute fibre cells are developed. The organ, however, never regains its original virgin character. Its weight usually remains from two to three ounces in those who have had children; its cavity is larger; the os externum is wider and more rounded, and its margins often puckered or fissured; the arteries continue much more tortuous than they are in the virgin, and its muscular fibres and layers remain more defined.

Age.—In the infant the neck of the uterus is larger than the body; and the fundus is not distinguished either by breadth or convexity of outline. These parts afterwards enlarge gradually, until, at puberty, the pyriform figure of the womb is fully established. The arbor vitæ is very distinct, and indeed at first reaches upwards to the highest part of the cavity.

From the gradual effects of more advanced *age* alone, independent of impregnation, the uterus shrinks, and becomes paler in colour, and harder in texture; its triangular form is lost; the body and neck become less distinguishable from each other; the orifices also become less characteristic.

For further details with regard to uterine changes, the reader is referred to Farre on "Uterus and its Appendages" in Cyclop. of Anat. and Phys.

THE OVARIES AND FALLOPIAN TUBES.

The *ovaries*, the parts corresponding to the testicles of the male (ovaria, testes muliebres), are two somewhat flattened oval bodies, which are placed one on each side, nearly horizontally, at the back of the broad ligament of the uterus, and are enveloped by its posterior membranous layer. The ovaries are largest in the virgin state; their weight is from three to five scruples, and they usually measure about one inch and a half in length, three-quarters of an inch in width, and nearly half an inch in thickness; but their size is rather variable. Each ovary is free on its two sides, and also along its posterior border, which has a convex outline; but it is attached by its anterior border, which is straighter than the other, and along the line of its attachment exhibits a deep *hilus* by which the vessels and nerves enter. Its inner end is generally narrow, and is attached to the dense cord already described as the *ligament* of the *ovary*, which connects it with the uterus. Its outer extremity is more obtuse and rounded, and has attached to it one of the fimbriæ of the Fallopian tube.

Structure.—The colour of the ovaries is whitish, and their surface is either smooth, or more commonly irregular, and often marked with pits or clefts resembling scars. Beneath the peritoneal coat, which covers it everywhere except along its attached border, the ovary is enclosed in a *proper fibrous coat* (tunica albuginea), of a whitish aspect and of considerable thickness, which adheres firmly to the tissue beneath, being in structural continuity with it. When the deeper ovarian substance is divided, it is seen to consist of a firm reddish-white vascular structure called the

Fig. 687.

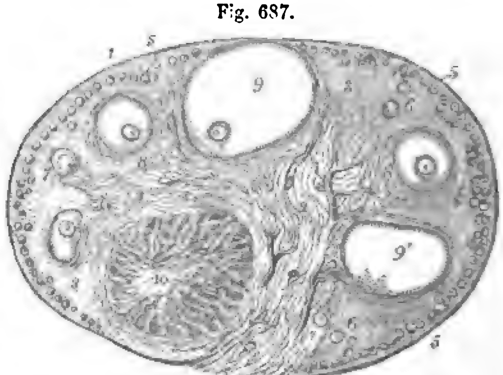


Fig. 687.—View of a Section of the prepared Ovary of the Cat (from Schron). ♀

1, outer covering and free border of the ovary; 1′, attached border; 2, the ovarian stroma, presenting a fibrous and vascular structure; 3, granular substance lying external to the fibrous stroma; 4, blood-vessels; 5, ovigerms in their earliest stages occupying a part of the granular layer near the surface; 6, ovigerms which have begun to enlarge and to pass more deeply into the ovary; 7, ovigerms round which the Graafian follicle and tunica granulosa are now formed, and which have passed somewhat deeper into the ovary and are surrounded by the fibrous stroma; 8, more advanced Graafian follicle with the ovum imbedded in the layer of cells constituting the proligerous disc; 9, the most advanced follicle containing the ovum, &c.: 9′, a follicle from which the ovum has accidentally escaped; 10, corpus luteum presenting radiated columns of cellular structure.

stroma, the fibres of which, although forming a felted tissue, have, with the blood-vessels, principally a radiating direction from the hilus to the rest of the surface. It contains numerous spindle-shaped cells, and also, according to some writers, unstriped muscular tissue. Towards the surface, the ovarian tissue, which in this part has been distinguished as *cortical*, presents, especially in children, a different appearance from the deeper or *medullary* part, from being granular, and having within it great numbers of small vesicles, the Graafian vesicles or follicles, which are absent from the deep part. After the period of puberty, a certain number of the Graafian vesicles, varying from twelve to thirty or more, have attained a larger size, some having a diameter of from $\frac{1}{20}$th to $\frac{1}{6}$th of an inch, or even more. The great majority, however, remain much smaller: thus Henle estimated the number of vesicles of about $\frac{1}{60}$ or $\frac{1}{80}$th of an inch in diameter, in the two ovaries of a girl of eighteen, at 72,000 (Syst. Anat., II., 483).

The *vesicles of De Graaf*, when dilated, are filled in part with a clear, colourless, albuminous fluid, the larger ones approaching the surface of the ovary, on which they may sometimes be distinguished as semi-transparent elevations. Each of these vesicles includes, besides its fluid contents, the *ovum*—a small round vesicular body, imbedded in a layer of cellular substance. Sometimes, though rarely, two ova have been found in one vesicle.

Fig. 688.

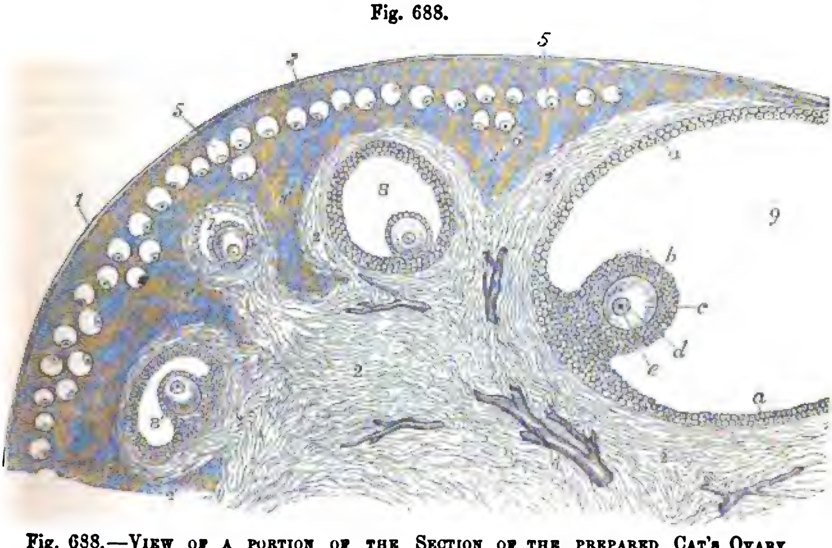


Fig. 688.—View of a portion of the Section of the prepared Cat's Ovary, represented in the preceding figure, more highly magnified (from Schron).

1, outer covering of the ovary; 2, fibrous stroma; 3, cortical layer of granular substance towards the surface; 3′, deeper parts of the granular substance; 4, blood-vessels; 5, ovigerms forming a layer near the surface; 6, one or two of the ovigerms sinking a little deeper and beginning to enlarge; 7, one of the ovigerms farther developed, now enclosed by a prolongation of the fibrous stroma, and consisting of a small Graafian follicle, within which is situated the ovum covered by the cells of the discus proligerus; 8, a follicle farther advanced; 8′, another which is irregularly compressed; 9, the greater part of the largest follicle, in which the following indications are given; *a*, epithelial or cellular lining of the follicle constituting the membrana granulosa; *b*, the portion reflected over the ovum named discus proligerus; *c*, vitellus or yelk part of the ovum surrounded by a vesicular membrane, which becomes afterwards the zona pellucida; *d*, germinal vesicle; *e*, germinal spot or nucleus.

The developed vesicle has two coats, viz., an external *vascular tunic*, and an internal tunic named the *ovi-capsule*, which is lined with a cellular or epithelial layer, the *membrana granulosa*. At first the ovum appears near the centre of the vesicle, while the latter is still very small, but, in the mature condition, it lies towards the internal surface of the ovi-capsule, imbedded in the *discus proligerus*, a small flattened heap of granular cells, continuous with the membrana granulosa.

The *ovum* itself, first discovered in mammals by Baër, is a spherical body, very constant in size, being about $\frac{1}{120}$th of an inch in diameter; it consists of a thick, colourless, and transparent envelope (zona pellucida), which surrounds the substance of the yelk. Within the yelk, which is made up of granular matter, is situated a still smaller vesicular body, named the *germinal vesicle*, which is about $\frac{1}{720}$th of an inch in diameter; and in this again is an opaque spot, having a diameter only of $\frac{1}{3500}$th to $\frac{1}{2500}$th of an inch, and named the *germinal spot* (macula germinativa).

The ova make their appearance in the ovary at so early a period that even at the time of birth it has been found too late to observe their mode of origin. It has been ascertained that the ovum makes its appearance before the ovisac, and that the germinal vesicle is the first part of the ovum to be formed, the granular substance of the yelk being gradually deposited round it. Around the ovum a circle of cells becomes visible, grows thicker, and divides into two layers, the outer of which becomes the membrana granulosa, while the inner adheres to the ovum, forming the discus proligerus. The precise nature and mode of origin of the inner tunic of the Graafian vesicle is matter of dispute, and indeed Henle denies that there is any homogeneous membrane distinct from the outer cells of the membrana granulosa.

According to Schrön's observations on the cat, the ova make their first appearance near the surface of the ovary, and the vesicles become deeper placed as they grow larger: it is only in the later stages of growth, when the great expansion of the vesicles presses aside the surrounding tissues, that they are again brought into contact with the surface. From observations by Gröhe it appears that the process is similar in the human ovary. A beaded arrangement of the ova, as if developed in anastomosing primitive gland tubes, has been observed by Valentin in the ovaries of young animals, and more recently by Pflüger in the adult cat. Spiegelberg finds similar appearances in the human fœtus. But the existence of such tubular glandular structure and its relation to the commencing ova is still under discussion, and requires farther observation for its determination.

Fig. 689.

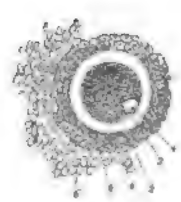


Fig. 689. — OVUM OF THE SOW REMOVED FROM THE GRAAFIAN VESICLE, WITH ITS CELLULAR COVERING (from M. Barry). $\frac{100}{1}$

1, germinal spot or nucleus: 2, germinal vesicle; 3, the yelk; 4, the zona pellucida or external covering of the ovum; 5, part of the tunica granulosa or proligerous disc; 6, some adherent granules or cells.

The Graafian vesicle, as it becomes more fully dilated, approaches the surface of the ovary. By rupture of the vesicle the ovum, covered by the cells of its proligerous disc, escapes into the Fallopian tube, and is thus conveyed into the womb, while the ruptured vesicle becomes converted, by hypertrophy of its walls, into a yellow mass named *corpus luteum*, which after persisting for a time, dwindles down into a small fibrous cicatrix.

On the subject of the ovum the following works may be mentioned:— Martin Barry's Researches on Embryology, in Phil. Trans., 1838 and 1839; Allen Thomson, Article "Ovum," in Cyclop. of Anat. and Phys., where also the literature will be found referred to; Farre, "Uterus and Appendages," in the same; Pflüger, Die Eierstöcke der Saügethiere und des Menschen, Leipzig, 1863; Schrön, in Zeitsch. f. Wissensch. Zoologie, vol. xji. p. 409; Gröhe, in Virchow's Archiv, vol. xxvi. p. 271; also in Virchow's Archiv, vol. xxix. p. 450; Spiegelberg, in Virchow's Archiv, vol. xxx. p. 466; and Henle, in his Handbuch.

The *Fallopian tubes.*—These tubes, which may be considered as ducts of the ovaries, or oviducts, and which serve to convey the ovum from thence into the uterus, are inclosed in the free margin of the broad ligaments. They are between three and four inches in length. Their inner or attached extremities, which proceed from the upper angles of the uterus, are narrow and cord-like; but they soon begin to enlarge, and proceeding outwards, one on each side, pursue an undulatory course, and at length, having become gradually wider, they bend backwards and downwards towards the ovary, about an inch beyond which they terminate in an expanded extremity, the margin of which is divided deeply into a number of irregular processes named *fimbriæ;* one of these, somewhat longer than the rest, is attached to the outer end of the corresponding ovary. The wide and fringed end of the Fallopian tube, or rather *trumpet*, as the term "tuba" literally signifies, is turned downwards and towards the ovary, and is named the *fimbriated extremity* (morsus diaboli). In the midst of these fimbriæ, which are arranged in a circle, the tube itself opens by a round constricted orifice, *ostium abdominale,* placed at the

Fig. 690.

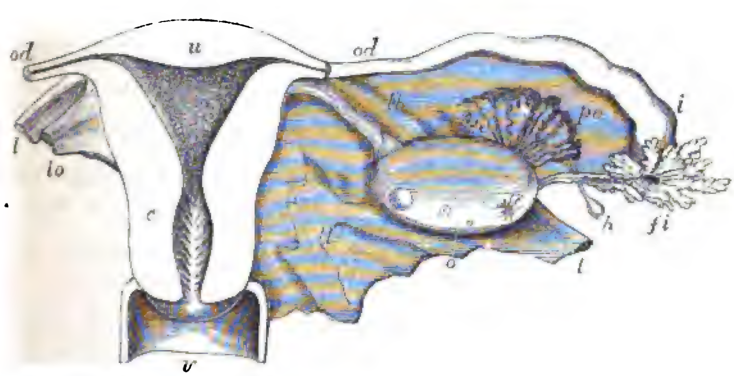


Fig. 690.—DIAGRAMMATIC VIEW OF THE UTERUS AND ITS APPENDAGES, AS SEEN FROM BEHIND. ½

The uterus and upper part of the vagina have been laid open by removing the posterior wall; the Fallopian tube, round ligament, and ovarian ligament have been cut short and the broad ligament removed on the left side; *u*, the upper part of the uterus; *c*, the cervix opposite the os internum; the triangular shape of the uterine cavity is shown and the dilatation of the cervical cavity with the rugæ termed arbor vitæ; *v*, upper part of the vagina; *od*, Fallopian tube or oviduct; the narrow communication of its cavity with that of the cornu of the uterus on each side is seen; *l*, round ligament; *lo*, ligament of the ovary; *o*, ovary; *i*, wide outer part of the right Fallopian tube; *f i*, its fimbriated extremity; *po*, parovarium; *h*, one of the hydatids frequently found connected with the broad ligament.

bottom of a sort of fissure leading from that fringe which is attached to the ovary. It is by this orifice that an ovum is received at the time of its liberation from the ovary, and is thence conveyed along the tube to its uterine extremity, which opens into the womb by a very minute orifice, admitting only a fine bristle, and named *ostium uterinum*. The part of the canal which is near the uterus is also very fine, but it becomes gradually larger towards its abdominal orifice, and there it is again somewhat contracted : hence, the term *isthmus* given by Henle to the uterine half, and *ampulla* to the outer half of the Fallopian tube.

Beneath the external or peritoneal coat the walls of the tube contain, besides areolar tissue, plain muscular fibres like those of the uterus, arranged in an external longitudinal and an internal circular layer. The mucous membrane lining the tubes is thrown into longitudinal plicæ, which are broad and numerous in the wider part of the tube, and in the narrower part are broken up into very numerous arborescent processes : it is continuous, on the one hand, with the lining membrane of the uterus, and at the outer end of the tube with the peritoneum ; presenting an example of the direct continuity of a mucous and serous membrane, and making the peritoneal cavity in the female an exception to the ordinary rule of serous cavities, i. e. of being perfectly closed. The epithelium in the interior of the Fallopian tube is, like that of the uterus, columnar and ciliated ; the inner surface of the fimbriæ is also provided with cilia, and Henle has even detected ciliated epithelium on their outer or serous surface, but it here soon passes into the scaly epithelium of the peritoneal membrane.

Vessels and nerves of the ovaries and Fallopian tubes.—The ovaries are supplied by the ovarian *arteries*, analogous to the spermatic in the male, which anastomose freely by an internal branch with the termination of the uterine arteries. Sometimes this anastomotic branch is so large that the ovary seems to be supplied almost entirely by the uterine artery. The ovarian artery always sends numerous branches to the Fallopian tube. The smaller arteries penetrate the ovary along its attached border, pierce the proper coat, and run in flexuous parallel lines through its substance. The *veins* correspond, and the ovarian veins form a plexus near the ovary named the pampiniform plexus. The *nerves* are derived from the spermatic or ovarian plexus; and also from one of the uterine nerves, which invariably send an offset to the Fallopian tube.

The *parovarium* (Kobelt), or Organ of Rosenmüller, is a structure which can usually be brought plainly into view by holding against the light the fold of peritoneum between the ovary and Fallopian tube. It consists of a group of scattered tubules lying transversely between the Fallopian tube and ovary, lined with epithelium, but having no orifice. The tubules converge, but remain separate at their ovarian end, and at the other are more or less distinctly united by a longitudinal tube. The parovarium consists of a few tubules formed in connection with the Wolffian body, which partaking in the growth of the surrounding textures have remained persistent during life. The duct which unites them is sometimes of considerable size, and is prolonged for some distance downwards, in the broad ligament. Its more developed form in some animals constitutes the duct of Gaertner, afterwards referred to as arising from a persistent condition of the Wolffian duct.

DEVELOPMENT OF THE URINARY ORGANS.

The *Wolffian Bodies* and their *Excretory ducts*.—The development of the genito-urinary organs in reptiles, birds, and mammalia, including man, is preceded by the formation of two *temporary* glands, named after their discoverer, C. F. Wolff, the

Wolffian Bodies. In the embryos of the higher mammalia these organs are proportionally smaller, and disappear earlier than in those of the lower mammalia, birds or reptiles. In the human subject, accordingly, the Wolffian bodies are relatively small, and are found only in an early stage of fœtal development. In the mammalian embryo, at a period when the intestinal canal still communicates with the umbilical vesicle by a wide orifice, the Wolffian bodies appear in the form of two slight ridges of blastema, placed one on each side of the line of attachment of the intestine to the vertebral column. On reaching their full size, which in man seems to take place about the fifth week of embryonic life, they have the appearance of two oblong reddish masses placed on the sides of the vertebral column, and extending from the lower end of the abdomen to the vicinity of the heart. Their structure is glandular; clear pedunculated vesicles may be early discovered in them, opening into an excretory duct which runs along the outer side of each organ. These vesicles subsequently become lengthened into transverse and somewhat tortuous cœcal tubes, which still retain a dilatation, like the capsule of a Malpighian body, at their inner extremity. The Wolffian bodies are highly vascular, their larger blood-vessels running between and parallel with the transverse tubules. In the embryo of the coluber natrix, Rathke first observed vascular tufts, which he compared to the Malpighian corpuscles of the kidneys; and since the time of his discovery, Malpighian tufts have been found in the Wolffian bodies of birds and mammals. The ducts of the two bodies open into the sac of the allantois, to be presently described.

Fig. 691.

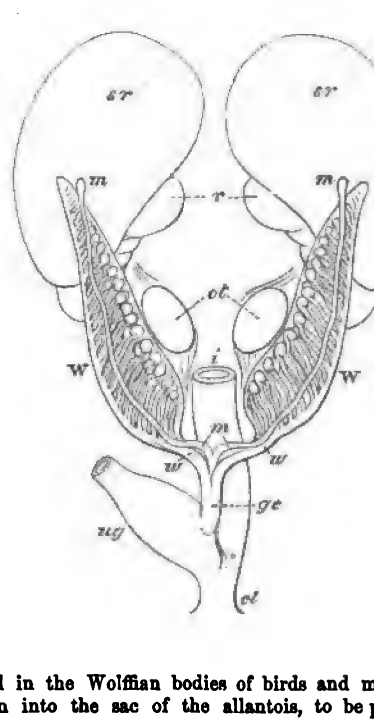


Fig. 691. — Diagram of the Wolffian Bodies, Müllerian Ducts and Adjacent Parts previous to Sexual Distinction, as seen from before.

ot, common blastema of ovaries or testicles; W, Wolffian bodies; *w*, Wolffian ducts; *m*, *m*, Müllerian ducts; *g c*, genital cord; *ug*, sinus uro-genitalis; *i*, intestine; *cl*, cloaca.

A whitish secretion has been seen in the ducts of the Wolffian bodies of birds and serpents resembling the urine of those animals, and as the fluid of the allantois also has been found to contain uric acid, it is reasonable to think that the Wolffian bodies perform the office of kidneys during the early part of fœtal life. They are accordingly sometimes named the *primitive* or *primordial kidneys.*

As development advances, the Wolffian bodies rapidly become proportionally shorter and thicker: they shrink towards the lower part of the abdominal cavity, and soon become almost entirely wasted. By the middle of the third month only traces of them are visible in the human embryo. They take no part in the formation of the kidneys or supra-renal capsules, nor in that of the ovaries or body of the testes, but are connected with the origin of a part of the seminal passages in the male sex.

The Kidneys and *Ureters.*—The *kidneys* commence subsequently to and independently of the Wolffian bodies. They already exist about the seventh week, as two small

dark oval masses, situated behind the upper part of the Wolffian bodies, which are still large and completely hide the kidneys. Though at first smooth and oval, the kidneys soon assume their characteristic general outline, and about the tenth week are distinctly lobulated. The separate lobules, generally about fifteen in number, gradually coalesce in the manner already described; but at birth, indications of the original lobulated condition of the kidney are still visible on the surface, and the entire organ is more globular in its general figure than in the adult. The kidneys are then also situated lower down than in after-life.

The formative blastema of the kidney, as observed by Rathke in the fœtal calf, soon contains a series of club-shaped bodies which have their larger ends free and turned outwards, and their smaller ends or pedicles directed inwards towards the future hilus, where they are blended together. As the organ grows these bodies increase in number, and finally, becoming hollow, form the *uriniferous tubes.* At first, short, wide, and dilated at their extremities, the tubuli soon become elongated, narrow, and flexuous, occupying the whole mass of the kidney, which then appears to consist of cortical substance only. At a subsequent period, the tubuli nearest the hilus become straighter, and thus form the medullary substance. The tubuli, as shown by Valentin, are absolutely, as well as relatively, wider in the early stages of formation of the kidney. The Malpighian corpuscles have been seen by Rathke in a sheep's embryo, the kidneys of which measured only two and a half lines in length.

With regard to the mode of the first appearance of the pelvis and ureter, the statements of embryologists are very conflicting. The *ureters*, it is stated by Rathke, commence *after* the kidneys, and then become connected with the hilus of each organ, and with the narrow ends of the club-shaped bodies in its interior. At first, according to him, the growing tubuli do not seem to communicate with the cavity of the ureter; but, subsequently, when the wide upper portion of this canal or *pelvis* of the kidney has become divided to form the future *calyces*, the pencil-like bundles of the tubuli open into each subdivision of the ureter, and give rise at a later period to the appearance of the *papillæ* and their numerous orifices. The lower ends of the ureters soon come to open into that part of the sac of the allantois which afterwards becomes converted into the bladder. The researches of Müller and Bischoff are in general confirmatory of Rathke's account. Valentin believes that the ureter (which he has seen at the earliest periods), the pelvis of the kidney, and the uriniferous tubules are formed in a general blastema, independently of one another; and that, each part first becoming separately hollowed out, their cavities afterwards communicate with each other. Bischoff states that the ureters appear at the same time as the kidneys, and are formed in continuity with the uriniferous tubules, and moreover that all these parts, which are at first solid, are excavated, not separately, but in common, in the farther progress of development. Lastly, according to Remak's observations on the chick, the kidneys of that animal commence as two hollow projections from the cloaca internal to the ducts of the Wolffian bodies, which afterwards elongate and ramify so as to form both the ureters and kidneys.

In the advanced fœtus and in the new-born infant, the kidneys are relatively larger than in the adult, the weight of both glands, compared with that of the body, being, according to Meckel, about one to eighty at birth.

The Supra-renal Bodies.—These organs have their origin from blastema, independent both of the kidneys and the Wolffian bodies. Valentin describes them as originating in a single mass, placed in front of the kidneys, and afterwards becoming divided. Meckel has also seen them partially blended together. Müller has found the supra-renal bodies in contact, but not united. Bischoff has always seen them separate, and in early conditions closely applied to the upper end of the Wolffian bodies. Kölliker has also observed them united by a bridge of substance, in which the splanchnic uerves were lost. From all this it is plain that the solar plexus and supra-renal capsules are closely united in the early fœtal state; but it by no means follows that they have a common origin.

In quadrupeds the supra-renal bodies are at all times smaller than the kidneys; but in the human embryo they are for a time larger than those organs, and quite conceal them. At about the tenth or twelfth week, the supra-renal bodies are smaller than the kidneys; at birth the proportion between them is 1 to 3, whilst in the adult it is about 1 to 22. They diminish in aged persons.

The Allantois, Urinary Bladder, and Urachus.—The name of Allantois was originally given to a membranous sac which is appended to the umbilicus of various quadrupeds in the fœtal state, and which communicates with the urinary bladder by means of a canal passing through the umbilical aperture, and named the urachus. These several parts are formed out of one original saccular process, which passes out from the cloacal termination of the intestine, and which subsequently becomes distinguished into the bladder, the urachus, and the allantois strictly so called; but modern embryologists employ the term allantois also to signify the original common representative of the several parts referred to. In this sense, an allantois may be said to exist not only in mammalia, but also in birds and reptiles, subject, however, to great differences in its subsequent development and relative importance. Thus in Batrachians it never extends beyond the abdominal cavity; in scaly reptiles, on the other hand, as well as in birds and in some quadrupeds, it ultimately surrounds the body of the fœtus, and spreads itself over the inner surface of the chorion or outer covering of the ovum, whilst in other quadrupeds its extra-abdominal portion is of small extent. In man, the allantois proper is not only very insignificant in point of size, but also extremely limited in duration, for it vanishes at a very early period in the life of the embryo: and whilst in many animals it serves both as a receptacle for the secretion of the fœtal urinary organs, and as a vehicle to conduct the umbilical vessels from the body of the embryo to the chorion to form the placenta (or some equivalent vascular structure), it seems in the human species to serve merely for the latter purpose. The allantoid process communicates below with the intestinal canal, and receives the wide excretory ducts of the Wolffian bodies, the ureters, and the Fallopian tubes or vasa deferentia. By Baër, Rathke, and others, the allantois has been regarded as formed from the intestinal tube, and by Reichert as developed upon the excretory ducts of the Wolffian bodies. Bischoff states that, in the embryos of the rabbit and dog, it commences before the appearance of either the Wolffian bodies or the intestine, as a solid mass projecting forwards from the posterior extremity of the body. This mass soon becomes hollowed into a vesicle, which is covered with blood-vessels, and communicates with the intestine. Continuing rapidly to enlarge, it protrudes between the visceral plates, and, when these close together, through the opening of the umbilicus, forming in the rabbit a pear-shaped sac, which conveys blood-vessels (soon recognised as the umbilical vessels) to the chorion, to form the fœtal part of the placenta.

In the human embryo, the allantois ceases, at a very early period, to be found beyond the umbilicus, and in the lower part of its extent, within the abdomen, it becomes widened to form the bladder, whilst the upper part, or urachus, becomes constricted, and is at length completely closed, and remains only in the form of a ligament, with minute traces of its original hollow structure already described along with the urinary bladder.

The lower part of the allantois, or rudimentary bladder, receiving, as already mentioned, the efferent canals of the Wolffian bodies, as well as those of the kidneys and of the ovaries or testes, at first communicates freely with the lower end of the intestinal tube, and when this becomes opened to the exterior, there is formed a sort of cloaca, as in adult birds and reptiles. Soon, however, a separation takes place, so as to produce for the genito-urinary organs a distinct passage to the exterior: this is named the *sinus uro-genitalis*, and is situated in front of the termination of the intestine.

DEVELOPMENT OF THE ORGANS OF GENERATION.

The development of the parts concerned in the reproductive function does not begin until after the rudiments of the principal organs of the body have appeared. The internal organs of generation first make their appearance, and for a brief period no sexual difference is perceptible in them. The external organs, which subsequently begin to be formed, are also identical in appearance in the two sexes, as late as the fourteenth week.

The Internal Organs of Generation.—The *Ovaries* and *Testes.*—The rudiments of the ovaries or testes, for it cannot at first be determined which are ultimately to be produced, appear after the formation of the allantois and Wolffian bodies, but a little sooner than the kidneys. They consist of two small whitish oval masses of blastema

placed on the inner border of the Wolffian bodies. At first, they are placed near to one another, and parallel; the Wolffian bodies being at that time large, and occupying the whole posterior part of the abdomen. But as the kidneys grow, above and internal to the Wolffian bodies, the latter are displaced outwards, and with them the reproductive organs. At this time the sex becomes distinguishable; for in the female the ovary becomes elongated and flattened, and it assumes at first an oblique and then a nearly transverse direction; whereas, in the male, the testis becomes rounder and thick, and, together with the Wolffian body, retains its vertical position, although displaced downwards and outwards. Subsequently the tubuli seminiferi are developed within the testis, and ova in the superficial strata of the ovary.

Fig. 692.

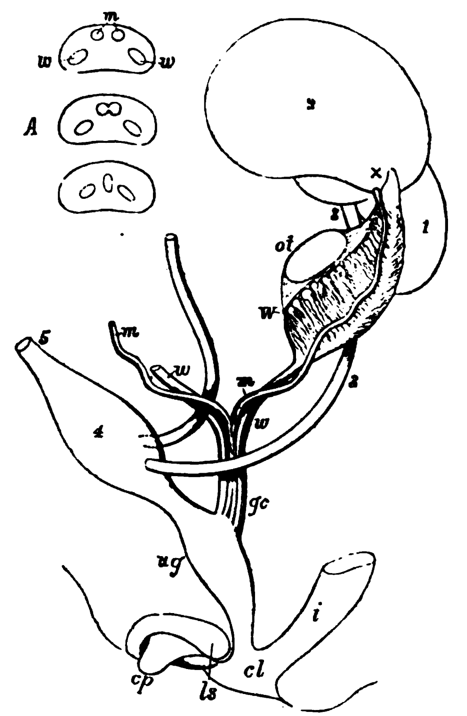


Fig. 692.—DIAGRAM OF THE PRIMITIVE URINARY AND SEXUAL ORGANS IN THE EMBRYO PREVIOUS TO SEXUAL DISTINCTION.

The parts are shown chiefly in profile; the kidney and supra-renal body of the right side are omitted, and the Müllerian and Wolffian ducts are shown from the front. 1, left kidney; 2 supra-renal body; 3, ureter; 4, urinary bladder; 5, urachus *o t*, the mass of blastema from which ovary or testicle is afterwards formed; W, left Wolffian body; ×, part at the apex from which the coni vasculosi are afterwards developed in new blastema; *w*, *w*, right and left Wolffian ducts; *m*, *m*, right and left Müllerian ducts uniting together and with the Wolffian ducts in *g c*, the genital cord; *u g*, sinus uro-genitalis; *i*, lower part of the intestine; *c l*, common opening of the intestine and uro-genital sinus; *c*, elevation which becomes clitoris or penis; *l s*, ridge from which the labia majora or scrotum is formed.

Uterus and Fallopian Tubes: Epididymis and Vasa Deferentia.—The excretory duct of each Wolffian body lies from the first along its outer border, and in the succeeding part of its course is continued down from the extremity of the Wolffian body to the sinus urogenitalis. As the Wolffian body begins to change its position, and at the same time decrease in size, a white thread of blastema appears on the front of that body, and runs along the inner side of the Wolffian duct in its whole course; this forms the *Müllerian duct*. At the upper extremity of the Wolffian body, and close to the white thread, there is likewise developed a pyramidal mass of blastema, occupying the position originally held by the upper tubules of that gland, which seem to be absorbed to give place to it. The Müllerian duct, commencing by a slightly dilated extremity, descends in front of the excretory duct, to the lower end of the Wolffian body, where it dips down in front of that body, then turns over that duct so as to get behind it, and on arriving at the middle line comes in contact with its fellow of the opposite side, with which, and with the lower parts of the Wolffian ducts, it is united into a single cord, named the *genital cord*. The Müllerian ducts become as it were fused together, first at the upper and lower parts of the genital

cord, and subsequently through its whole extent, while the Wolffian ducts remain separate to their ends.

Another structure is likewise seen at this stage in connection with the Wolffian body in both sexes, viz. an elevation of peritoneum, with tissue enclosed, which extends from the lower end of the testis or ovary to the point where the excretory and Müllerian ducts quit their contact with the lower extremity of the Wolffian body, and there becoming stronger, extends onwards from this point to the processus vaginalis or canal of Nuck. The further development of these parts in each of the two sexes requires a separate description.

Fig. 693.

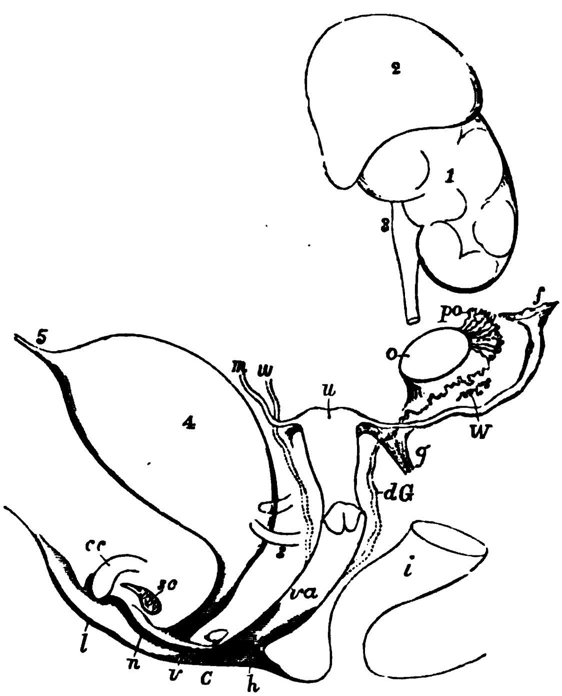


Fig. 693. — Diagram of the Female Type of Sexual Organs.

This and the following figure represent diagrammatically a state of the parts not actually visible at one time; but they are intended to illustrate the general type in the two sexes, and more particularly the relation of the two conducting tubes to the development of one as the natural passage in either sex, and to the natural occurrence of vestiges of the other tube, as well as to the persistence of the whole or parts of both tubes in occasional instances of hermaphroditic nature.

1, the left kidney; 2, supra-renal body; 3, ureter, of which a part is removed to show the parts passing within it; 4, urinary bladder; 5, urachus; *o*, the left ovary nearly in the place of its original formation; *p o*, parovarium; W, scattered remains of Wolffian tubes near it; *d* G, remains of the left Wolffian duct, such as give rise to the duct of Gaertner, represented by dotted lines; that of the right side cut short is marked *w*; *f*, the abdominal opening of the left Fallopian tube; *u*, the upper part of the body of the uterus, presenting a slight appearance of division into cornua; the Fallopian tube of the right side cut short is marked *m*; *g*, round ligament, corresponding to gubernaculum; *i*, lower part of the intestine; *v a*, vagina; *h*, situation of the hymen; C, gland of Bartholin Cowper's gland), and immediately above it the urethra; *c c*, corpus cavernosum clitoridis; *s c*, vascular bulb or corpus spongiosum; *n*, nympha; *l*, labium; *v*, vulva.

In the female, the vagina, uterus, and Fallopian tubes are formed out of the Müllerian ducts. That portion of the ducts in which they become fused together is developed into the vagina, the cervix, and part of the body of the uterus; and the peculiarity of the mode of fusion accounts for the occurrence, as a rare anomaly, not only of double uterus, but of duplicity of the vagina, coincident with communication between two lateral halves of the uterus. The part of the Müllerian duct extending from the base of the Wolffian body, to the point where the two ducts meet, constitutes

in animals with horned uteri, the cornu of the uterus; but in the human subject it remains comparatively short, entering into the formation of the upper part of the organ. The remaining upper portion of the Müllerian duct constitutes the Fallopian tube—becoming at first open and subsequently fringed at its upper extremity. In the peritoneal elevation between the ovary and the base of the Wolffian body the fibrous ligament of the ovary is developed, while that part which proceeds onwards to the canal of Nuck becomes the round ligament of the uterus. The excretory ducts of the Wolffian bodies disappear in the human female, but in the pig and some ruminants they persist as the canals of Gaertner. The parovarium is generally believed to consist of the vestiges of some of the tubules of the Wolffian body, but it is held by Banks, to

Fig. 694.

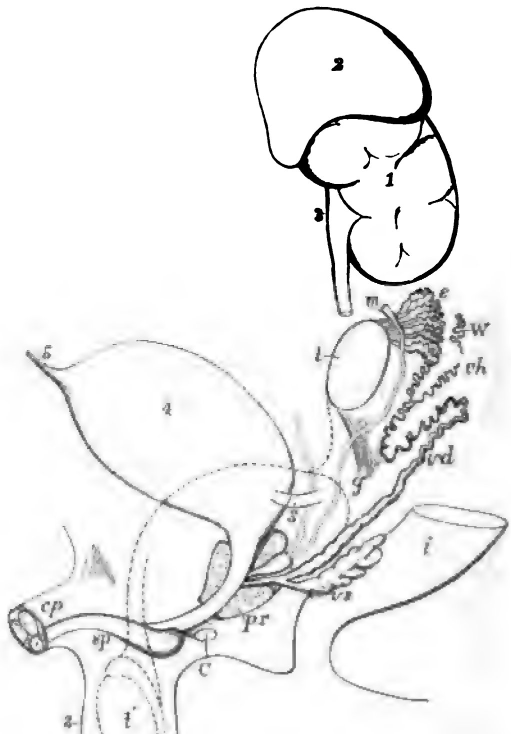


Fig. 694.—Diagram of the Male Type of Sexual Organs.

1, 2, 3, 4, and 5, as in the preceding figure; *t*, testicle in the place of its original formation; *e*, caput epididymis; *v d*, vas deferens; W, scattered remains of the Wolffian body constituting the organ of Giraldès; *v h*, vas aberrans; *m*, Müllerian duct, the upper part of which remains as the hydatid of Morgagni, the lower part represented by a dotted line as descending to the sinus pocularis constitutes the cornu and tube of the uterus masculinus; *g*, the gubernaculum; *v s*, the vesicula seminalis; *pr*, the prostate gland; C, Cowper's gland of one side; *cp*, corpora cavernosa penis cut short; *s p*, corpus spongiosum urethræ; *s*, scrotum; *t'*, together with the dotted lines above, indicates the direction in which the testicle and epididymis change place in their descent from the abdomen into the scrotum.

owe its origin to a development of tubes in the whitish blastema previously mentioned, which appears in connection with the upper part of that body when it begins to shrink, and which, in the male, gives rise to the upper part of the epididymis; and in this view Allen Thomson is disposed to concur.

In the male the Müllerian ducts are destined to undergo little development, and are of no physiological importance, while the ducts of the Wolffian bodies, and probably also some part of their glandular substance, form the principal part of the excretory apparatus of the testicle. The united portion of the Müllerian ducts remains as the vesicula prostatica, which accordingly not only corresponds with the uterus, as was shown by Weber, but likewise, as pointed out by Leuckart, contains as much of the vagina as is represented in the male. In some animals the vesicula prostatica is prolonged into cornua and tubes; but in the human subject the whole of the

ununited parts of the Müllerian ducts disappear, excepting, as suggested by Kobelt, their upper extremities, which seem to be the source of the hydatids of Morgagni. The excretory duct of the Wolffian body, from the base of that body to its orifice, is converted into vas deferens and ejaculatory duct, the vesicula seminalis being formed as a diverticulum from its lower part.

With respect to the formation of the epididymis, our information is not altogether complete. According to the greater number of the most recent observations, it appears certain that the larger convoluted seminal tube, which forms the body and globus minor of the epididymis, arises by a change or adaptation of that part of the Wolffian duct which runs along the outer side of the organ. The vas aberrans or vasa aberrantia of Haller appear to be the remains also in a more highly convoluted form of one or more of the tubes of the Wolffian body still adhering to the excretory duct of the organ, and their communication with the main tube of the epididymis receives an explanation from that circumstance. But there are no direct observations on record of the process of conversion of these fœtal structures into the permanent forms. As to the coni vasculosi in the upper part of the epididymis, still more doubt has prevailed. Since Müller's discovery in birds of the collateral duct named after him, and the extension of this discovery to mammals, it has been customary to regard the upper part of the epididymis as produced by a transformation of the tubes and duct in the upper part of the Wolffian body, according to the views most fully given by Kobelt; but doubts have been entertained by some as to the correctness of this view, and more recent observations by Banks appear to prove that it must, in some degree, be modified.

According to Banks the origin of the coni vasculosi is due to a process of development occurring in a new structure or mass of blastema which had been previously observed by Cleland, and which is deposited at the upper end of the Wolffian body, and close to the Müllerian duct. Within this blastema Cleland showed that the tubes of the efferent seminal vessels and the coni vasculosi, together with the tube which connects them, are formed anew, while the tubes of the adjacent part of the Wolffian body are undergoing an atrophic degeneration. This has been confirmed by the detailed observations of Banks, who has further shown the continuity of their uniting tube with the Wolffian excretory duct.

Should this view prove to be correct the caput epididymis must be regarded not simply as a conversion of the upper part of the Wolffian body, but rather as a new formation or superinduced development in blastema connected with it.

The coni vasculosi, so formed, become connected with the body of the testicle by means of a short straight cord, which is afterwards subdivided into the vasa efferentia. The peritoneal elevation descending from the testis towards the lower extremity of the Wolffian body is the upper part of the plica gubernatrix, and becomes shortened as the testicle descends to meet the lower end of the epididymis; the peritoneal elevation which passes down into the scrotum, and is continuous with the other, is the more important part of the plica gubernatrix, connected with the gubernaculum testis. The spermatic artery is originally a branch of one of those which go to the Wolffian body, and ascends from the surface of the Wolffian body to the upper part of the testis, along the ligaments connecting them; but, as the testis descends, the artery lies entirely above it, and the secreting substance of the Wolffian body remains adherent to it; and hence it is that the organ of Giraldès, which consists of persistent Wolffian tubules, is found in a position superior to the epididymis. (For a fuller account of this complicated subject the student is referred to Banks "On the Wolffian Bodies." Edin. 1864.)

The *descent of the testicles* is a term applied to the passage of the testes from the abdominal cavity into the scrotum. The testicle enters the internal inguinal ring in the seventh month of fœtal life: by the end of the eighth month it has descended into the scrotum, and a little time before birth, the narrow neck of the peritoneal pouch, by which it previously communicated with the general peritoneal cavity, becomes closed in the manner elsewhere described (p. 965), and the process of peritoneum, now entirely shut off from the abdominal cavity, remains as an independent serous sac. The peritoneal pouch, or processus vaginalis, which passes down into the scrotum, precedes the testis considerably in its descent, and into its posterior part there projects a considerable columnar elevation already alluded to, which is filled with soft tissue, and is termed *plica gubernatrix*. There is likewise a fibrous struc-

ture attached inferiorly to the lower part of the scrotum, and surrounding the peritoneal pouch above, which may be distinguished as the *gubernacular cord*, both this and the plica gubernatrix being included in the general term *gubernaculum testis* (J. Hunter). The gubernacular cord consists of fibres which pass downwards from the sub-peritoneal fascia, others which pass upwards from the superficial fascia and integument, and others again which pass both upwards and downwards from the internal oblique muscle and the aponeurosis of the external oblique; it exhibits, therefore, a fusion of the layers of the abdominal wall. Superiorly, it surrounds the processus vaginalis, without penetrating the plica gubernatrix; and the processus vaginalis, as it grows, pushes its way down through the gubernacular cord and disperses its fibres. By the time that the testis enters the internal abdominal ring, the processus vaginalis has reached a considerable way into the scrotum; and as the testis follows, the plica gubernatrix becomes shorter, till it at last disappears, but it cannot be said that the shortening of the plica is the cause of the descent of the testicle, and much less (as has been held by some) that the muscular fibres of the gubernacular cord are the agents which effect this change of position. The arched fibres of the cremaster muscle make their appearance on the surface of the processus vaginalis as it descends, while its other fibres are those which descend in the gubernacular cord. (See for a further account of this process, and the various views which have been held with regard to the descent of the testicles, Cleland, "Mechanism of the Gubernaculum Testis." Edinburgh, 1856.)

The External Organs of Generation.—In the human subject these have for some time the same form in both sexes; but in animals in which the penis is prolonged to the umbilicus, that circumstance forms one of the very earliest sexual distinctions, inasmuch as the clitoris hangs free.

Fig. 695.

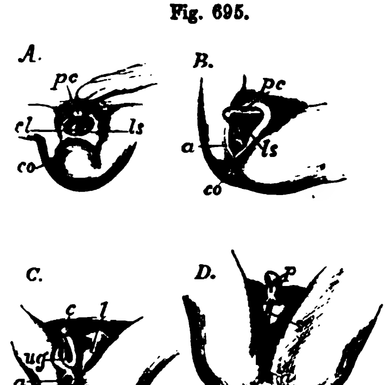


Fig. 695.—Development of the External Sexual Organs in the Male and Female from the Indifferent Type (from Ecker).

A, the external sexual organs in an embryo of about nine weeks, in which sexual distinction is not yet established, and the cloaca still exists: B, the same in an embryo somewhat more advanced, and in which, without marked sexual distinction, the anus is now separated from the uro-genital aperture: C, the same in an embryo of about ten weeks, showing the female type: D, the same in a male embryo somewhat more advanced. Throughout the figures the following indications are employed: *pc*, common blastema of penis or clitoris; to the right of these letters in A, the umbilical cord; *p*, penis; *c*, clitoris; *cl*, cloaca; *ug*, urogenital opening; *a*, anus; *s*, cutaneous elevation which becomes labium or scrotum; *l*, labium; *s*, scrotum; *c o*, coccygeal elevation.

Up to the fifth week, according to Tiedemann, there is no separate genito-urinary orifice, and indeed no anus. Previous to this period, or about the beginning of the fourth week, there is a common opening, for the intestine, the generative, and the urinary organs, *i. e.*, a *cloacal* aperture. In front of this simple opening, there soon appears a small recurved projecting body, which, as it enlarges, becomes grooved along the whole of its under surface. This is the rudimentary *clitoris*, or *penis*, at the summit of which an enlargement is formed which becomes the *glans*. The margins of the groove seen on its under surface are continued backwards on either side of the common aperture, which is now elliptical, and is bounded laterally by two large cutaneous folds. Towards the tenth or eleventh week, a transverse band, the commencing *perinæum*, divides the anal orifice from that of the genito-urinary passage, which latter now appears as a rounded aperture, placed below the root of

the rudimentary clitoris or penis, and between the prolonged margins of the groove beneath that organ. This opening, but not the clitoris or penis, is concealed by the large cutaneous folds already mentioned. In this condition, which continues until the twelfth week, the parts appear alike in both sexes, and resemble very much the perfect female organs. The rudiments of *Cowper's glands* are, it is said, seen at an early period, near the root of the rudimentary clitoris or penis, on each side of the genito-urinary passage.

In the female, the two lateral cutaneous folds enlarge, so as to cover the clitoris and form the *labia majora*. The clitoris itself remains relatively smaller, and the groove on its under surface less and less marked, owing to the opening out and subsequent extension backwards of its margins to form the *nymphæ*. The *hymen* begins to appear about the fifth month. Within the nymphæ, the urethral orifice, as already mentioned, becomes distinct from that of the vagina.

In the male, on the contrary, the *penis* continues to enlarge, and the margins ot the groove along its under surface gradually unite from the primitive urethral orifice behind, as far forward as the glans, so as to complete the long canal of the male *urethra*. This is accomplished about the fifteenth week. When this union remains incomplete, the condition named hypospadias is produced. In the meantime the *prepuce* is formed, and, moreover, the lateral cutaneous folds also unite from behind forwards, along the middle line or *raphé*, and thus complete the *scrotum* into which the testicles do not descend until the last month of fœtal existence.

The following tabular scheme of the corresponding parts of the genito-urinary organs in the two sexes, and of their relation to the formative rudiments of the common embryonic type, may be useful in fixing attention on the more important points of the subject.

FEMALE.	COMMON EMBRYONIC.	MALE.
Ovary	I.—Common reproductive gland	Body of Testicle.
	II.—Wolffian body.	
Parovarium	1. New blastema at upper part	Coni vasculosi.
Irregular vestiges near parovarium (?)	2. Tubular substance of the gland	Organ of Geraldès. Vasa aberrantia.
Duct of Gaertner in some animals	3. Excretory duct along the gland	Convoluted tube of epididymis.
	4. Duct below the gland	Vas deferens.
	III.—Duct of Müller.	
Fimbriæ and Fallopian tube	1. Upper end and part along the Wolffian gland	Hydatid of Morgagni and other vestigial vesicles.
Cornu uteri	2. Free part of duct	Cornu of sinus pocularis in some animals.
Uterus and vagina	3. Fused part of both ducts in the genital cord	Sinus pocularis.
Female urethra	IV.—Pedicle of the allantois	Upper portion of prostatic part of urethra.
Vestibule	V.—Sinus urogenitalis	Lower portion of prostatic with membranous part of urethra.
Glands of Bartholin	Common blastema	Glands of Cowper.
	VI.—Common sexual prominence and integumental folds.	
Corpora cavernosa clitoridis	1. Common blastema	Corpora cavernosa penis.
Labia majora	2. Outer integumental folds	Scrotum.
Nymphæ	3. Inner integumental folds	Integument of lower surface of penis.
Vestibular bulbs and other erectile tissue	4. Common blastema	Bulb and corpus spongiosum urethræ.
	VII.—Peritoneal folds and gubernacular bands.	
Canal of Nuck	1. Inguinal peritoneal pouch	Processus vaginalis.
Ovarian ligament	2. Band from genital gland to base of Wolffian body	Tissue connecting testicle and globus minor.
Round ligament of uterus	3. Band descending from base of Wolffian body	Gubernaculum testis.

MAMMARY GLANDS.

The mammary glands (mammæ), the organs of lactation in the female, are accessory parts to the reproductive system. They give a name to a large class of animals (Mammalia), which are distinguished by the possession of these organs. When fully developed in the human female, they form, together with the integuments and a considerable quantity of fat, two rounded eminences (the breasts) placed one at each side on the front of the thorax. These extend from the third to the sixth or seventh rib, and from the side of the sternum to the axilla. A little below the centre of each breast, on a level with the fourth rib, projects a small conical body named the *nipple* (mamilla), which points somewhat outwards and upwards. The surface of the nipple is dark, and around it there is a coloured circle or *areola*, within which the skin is also of a darker tinge than elsewhere. In the virgin, these parts are of a rosy pink colour, but they are always darker in women who have borne children. Even in the second month of pregnancy the areola begins to enlarge and acquire a darker tinge; these changes go on increasing as gestation advances, and are regarded as reliable signs in judging of suspected pregnancy. After lactation is over, the dark colour subsides, but not entirely. The skin of the nipple is marked with many wrinkles, and is covered with papillæ; besides this, it is perforated at the tip by numerous foramina, which are the openings of the lactiferous ducts: and near its base, as well as upon the surface of the areola, there are scattered rounded elevations, which are caused by the presence of little glands with branched ducts, four or five of which open on each elevation. The tissue of the nipple contains a large number of vessels, together with much plain muscular tissue, and its papillæ are highly sensitive; it is capable of a certain degree of erection from mechanical excitement, which may be partly caused by turgescence of its vessels, but is probably due, in greater part, to contraction of the muscular fibres.

The base of the mammary gland, which is nearly circular, is flattened, or slightly concave, and has its longest diameter directed upwards and outwards towards the axilla. It rests on the pectoral muscle, and is connected to it by a layer of areolar tissue. The thickest part of the gland is near the centre, opposite the nipple, but the full and even form of the breasts depends chiefly on the presence of a large quantity of fat, which lies beneath the skin, covers the substance of the gland, and penetrates the intervals between its lobes and lobules. This fatty tissue, which is of a bright yellow tinge and rather firm, is divided into lobulated masses by numerous laminæ of fibrous or very dense areolar tissue, which are connected with the skin on the one hand, and on the other with the firm areolar investment of the gland itself, which investment is connected behind by similar laminæ with the areolar membrane covering the pectoral muscle: these laminæ serve to support the gland. Beneath the areola and the nipple there is no fat, but merely the firm areolar tissue and vessels surrounding the lactiferous ducts.

Structure.—The mammary gland consists of a number of distinct glandular masses or lobes, each having a separate excretory duct, held together by a very firm intervening fibrous or areolar tissue, and having some adipose tissue penetrating between them. Each of these divisions of the gland is again subdivided into smaller lobes, and these again into smaller and smaller lobules, which are flattened or depressed, and held together by areolar tissue, blood-vessels, and ducts. The substance of the

lobules, especially as contrasted with the adjacent fat, is of a pale, reddish cream-colour, and is rather firm. It is composed principally of the vesicular commencements of the lactiferous ducts, which appear like clusters of minute rounded cells, having a diameter from ten to thirty times as great

Fig. 696.

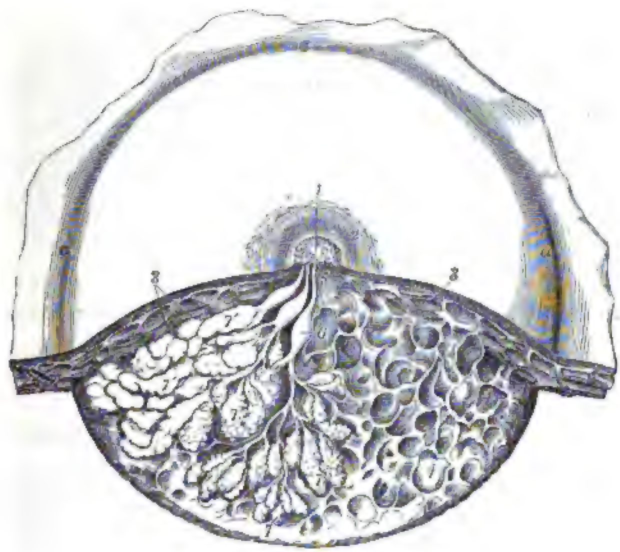


Fig. 696.—Dissection of the lower half of the Female Mamma during the period of Lactation (from Luschka). ¾

In the left-hand side of the dissected part the glandular lobes are exposed and partially unravelled; and in the right-hand side, the glandular substance has been removed to show the reticular loculi of the connective tissue in which the glandular lobules are placed: 1, upper part of the mamilla; 2, areola; 3, subcutaneous masses of fat; 4, reticular loculi of the connective tissue which support the glandular substance and contain the fatty masses; 5, one of three lactiferous ducts shown passing towards the mamilla where they open; 6, one of the sinus lactei or reservoirs; 7, some of the glandular lobules which have been unravelled; 7, others massed together.

as that of the capillary vessels by which they are surrounded. These cells open into the smallest branched ducts, which, uniting together to form others of larger size, finally end in a single excretory canal corresponding to one of the chief subdivisions of the gland. The canals proceeding thus from the principal lobes composing the gland are named the *galactophorous ducts*, and are from fifteen to twenty in number; they converge towards the areola, beneath which they become considerably dilated, especially during lactation, so as to form *sacs* or *sinuses* two or even three lines wide, which serve as temporary though small reservoirs for the milk. At the base of the nipple all these ducts, again reduced in size, are assembled together, those in the centre being the largest, and then proceed side by side, surrounded by areolar tissue and vessels, and without communicating with each other, to the summit of the mamilla, where they open by separate orifices: these orifices are seated in little depressions, and are smaller than the ducts to which they respectively belong. The walls of the ducts are composed of areolar tissue, with longitudinal and circular elastic filaments.

The mucous membrane is continuous with the common integument at the orifices of the ducts; its epithelium is scaly or tesselated, and in the smallest ducts and their ultimate vesicles consists of cells having a diameter very little exceeding that of their nuclei.

Fig. 697.

Fig. 697.—MAGNIFIED VIEWS OF THE GLANDULAR SUBSTANCE OF THE MAMMA DURING THE PERIOD OF LACTATION (from Henle).

A, section of a small lobule of the gland, magnified 60 diameters; 1, stroma of connective tissue supporting the glandular tissue; 2, terminal ramuscule of one of the gland tubes; 3, glandular vesicles.

B, four glandular vesicles magnified 200 diameters, showing the lining epithelial cells and some milk globules within them.

Blood-vessels and Nerves.—The *arteries* which supply the mammary glands are the long thoracic and some other branches of the axillary artery, the internal mammary, and the subjacent intercostals. The *veins* have the same denomination. Haller described a sort of anastomotic venous circle surrounding the base of the nipple as the *circulus venosus*. The *nerves* proceed from the anterior and middle intercostal cutaneous branches.

In the *male*, the mammary gland and all its parts exist, but quite in a rudimentary state, the gland itself measuring only about six or seven lines across, and two lines thick, instead of four inches and a half wide and one and a half thick, as in the female. Occasionally the male mamma, especially in young subjects, enlarges and pours out a thin watery fluid; and, in some rare cases, it has secreted milk.

Varieties.—Two or even three nipples have been found on one gland. An additional mamma is sometimes met with, and even four or five have been observed to co-exist; the supernumerary glands being most frequently near the ordinary pair, but sometimes in a distant part of the body, as the axilla, thigh, or back.

DIVISION II.

SURGICAL ANATOMY.

I.—SURGICAL ANATOMY OF THE ARTERIES.

In the description of the several blood-vessels, the points bearing on operative surgery have been indicated in detail. The leading facts to be attended to by the surgeon in the operation of placing a ligature on the chief arterial trunks will be now collectively considered.*

SURGICAL ANATOMY OF THE COMMON CAROTID ARTERY.

The common carotid artery does not furnish any branch, save in very rare instances. In a practical or surgical point of view, the branches arising sometimes close to its upper end may be disregarded, so that a ligature can be applied to any part of the vessel, except immediately at its commencement or termination. When the case is such as to allow a choice, the point which combines the most favourable circumstances for the operation, is opposite the lower end of the larynx. Here a large space would, in ordinary cases, intervene between the ligature and the ends of the vessel; and at the same time this part is free from the difficulties offered by the muscles lower down, and by the superior thyroid veins, if the artery be secured near its bifurcation. But it has been shown (p. 345) that the carotid artery occasionally bifurcates below the usual position—opposite the lower margin of the larynx, and even, however rarely, lower than this. In such cases, should the artery be laid bare at the point of division, it would be best to tie the two parts separately, close to their origin, in preference to tying the common trunk near its end. If, in consequence of very early division of the common carotid or its entire absence (cases which, however, are of extremely rare occurrence), two arteries (the external and internal carotids) should happen to come into view in the operation supposed, the most judicious course would doubtless be to place the ligature on that artery, which, upon trial, as by pressure, should prove to be connected with the disease.

In performing the operation, the direction of the vessel and the inner margin of the sterno-mastoid muscle are the surgeon's guides for the line of incision. Before dividing the integument it is well to ascertain whether the anterior jugular vein be in the line of incision. Should the operation be performed at the lower part of the neck, some fibres of the muscles will require to be cut across in order to lay the artery bare with facility; and the necessity for this step increases in approaching towards the clavicle. After the super-

* The plates referred to in this section are those of Richard Quain "On the Arteries."

ficial structures have been divided, assistance will be derived from the trachea or the larynx, as well as from the pulsation, in determining the exact situation of the artery. The trachea, from its roughness, may be

Fig. 698.

Fig. 698.—View of the Right Common Carotid and Subclavian Arteries, with the Origin of their Branches and their Relations (from R. Quain). ½

e, front of the hyoid bone; *f*, thyroid cartilage; *g*, isthmus of the thyroid gland; *h*, the trachea above the inter-clavicular notch of the sternum; *i*, *i'*, the sawn ends of the clavicle, the portion between them having been removed; *k*, the first rib; *m*, scalenus medius; *p*, on the longus colli muscle, pointing to the pneumogastric nerve; IV, the uppermost of the nerves of the axillary plexus; A, the innominate artery; 1, right common carotid artery; 1', placed on the left sterno-thyroid muscle, points to a part of the left common carotid; 2, internal carotid; 2', upper part of the internal jugular vein, which has been removed between *i*, and 2'; 3, and 4, external carotid; 3, is placed at the origin of the superior thyroid artery; 4, at that of the lingual; 5, the superior thyroid artery; 5', the thyroid or glandular branch; 8, the first part, 8', the third part of the arch of the subclavian artery; 8", the subclavian vein separated from the artery by the scalenus anticus muscle; 9, is placed on the scalenus anticus muscle in the angle between the transversalis colli and supra-scapular branches of the thyroid axis; 10,

outer part of the supra-scapular artery; 10′, transverse cervical branches passing into the deep surface of the trapezius; 10″, the posterior scapular artery, represented as rising directly from the third part of the subclavian artery, and passing through the axillary plexus of nerves and under the levator anguli scapulæ; 11, on the scalenus anticus muscle, points to the inferior thyroid artery near the place where the ascending muscular artery of the neck is given off; the phrenic nerve lies on the muscle to the outside; at *i*, the supra-sternal twig of the supra-scapular artery is shown.

readily felt in the wound, even while the parts covering it have still some thickness. The sheath of the vessels is to be opened over the artery—near the trachea—for thus the jugular vein is most easily avoided. This vein, should it lie in front of the artery, as it sometimes does on the left side, and especially at the lower part of the neck on that side, will be a source of much difficulty in completing the operation, *i. e.*, in passing the aneurism needle with the ligature about the artery. To surmount the difficulty much caution is required. The operator will find it advantageous to have the circulation in the vein (which in such operations becomes turgid and very large) arrested at the upper end of the wound by means of an assistant's finger. In most cases, if not in all, it is best to insert the aneurism needle conveying the ligature on the outer side of the artery, for thus the vagus nerve and the jugular vein will be most effectually avoided.

SURGICAL ANATOMY OF THE SUBCLAVIAN ARTERIES.

The subclavian artery is so deeply placed, its connections with important parts are so intimate and varied, and the branches are so large in proportion to the length of the trunk, that operations on this vessel present, in most cases, considerable difficulties to the surgeon. But the difficulties, it will be found, vary in different cases.

The last division of the artery, that beyond the anterior scalenus muscle (p. 366), is the part which is most favourably circumstanced for the application of a ligature in the case in which such an operation is most frequently called for, namely, aneurism affecting the artery in the axilla. This part is preferable chiefly because the vessel is here nearest to the surface and most remote from the origin of the large branches. But though the subclavian artery appears to be easy of access above the clavicle while the parts are in their natural position, it is to be remembered that when an aneurism exists in the axilla, the clavicle may be so much elevated in consequence of the presence of the tumour, as to be placed in front of the vessel, or even above it. In such circumstances, the artery lies at a great depth, and at the same time the structures in front and behind it (the clavicle on the one hand, the vertebræ with the muscles covering them on the other hand,) cannot, in any degree, be drawn asunder to facilitate the steps of the operation. It is when the outer part of the clavicle is thus raised from the ordinary horizontal position, that the height to which the artery arches above the bone becomes a point of importance. In most cases it happens that a portion of the artery is a short distance (about an inch) above the clavicle [plate 3]; but occasionally, as before mentioned (p. 367), it rises much higher [plate 20, fig. 3]; or it may be lower than usual, lying close behind the bone [fig. 2]. If, in a case rendering the operation necessary, the clavicle should be unusually raised, the accessibility of the vessel in the neck will differ in these several conditions: in one, the artery could be arrived at only by proceeding from above downwards behind the bone; in another, a part of it would still be higher than the bone. This will serve, in part at least, to account for differences in the time which the operation for tying the subclavian artery has occupied in the

hands of different surgeons, and even in the hands of the same surgeon in different cases.*

The principal facts bearing on the actual performance of an operation on the third part of the subclavian artery, will now be briefly recalled. The most prominent or convex part of the clavicle, the part of the bone opposite which the vessel lies, will serve as a guide for the middle of the first incision, which is to be made a little above the clavicle, and parallel with it. If (after noting with the eye, or marking on the surface the line at which it is desired to make the incision,) the integument be drawn downwards over the clavicle, the parts covering the bone may be divided with freedom.

With the integument, the platysma and several nerves are divided in this incision, but no vessel is endangered, except in those rare cases in which the cephalic vein or the external jugular crosses over the clavicle [plate 25, figs. 4, 5]. It will, in most cases, be an advantage to add a short vertical incision, directed downwards to the middle of the horizontal one. Should the sterno-mastoid muscle be broad at its lower end, or should the interval between that muscle and the trapezius be insufficient for the farther steps of the operation, a portion of the former muscle, or even of both muscles, must be divided [plate 25, fig. 7].

The external jugular vein next presents itself with the veins joining it from the shoulder, and, as this vein is usually over the artery, it must be held aside, or it may be necessary to divide it. If divided, the lower end of the vessel requires the application of a ligature as well as the upper one, in consequence of the reflux of blood from the subclavian vein. The omo-hyoid muscle will be turned aside if necessary; and now must be determined the exact position at which the artery is to be sought by division of the deeper fascia. If the clavicle has its usual horizontal direction, the first rib is the best guide to the vessel. The brachial nerves are here, it is to be remembered, close to the vessel,—so much so, that the ligature has in several cases been passed in the first instance round one of them instead of the artery. But if, in consequence of the disease rendering the operation necessary, the outer end of the clavicle is much raised, then it will, in many cases, be more easy to place the ligature on the artery above the insertion of the scalenus muscle, or even behind that muscle. Above the first rib, the situation of the vessel may be ascertained by means of the brachial nerves and the scalenus muscle; and, before the membrane covering them is divided, the position of these structures may be ascertained by the difference they offer to the touch. The cord-like nerves and the smooth flat muscle may thus be readily distinguished. At the same time the influence of pressure at a particular point in controlling the pulsation in the aneurism, will in this, as in other operations on the arteries, assist the surgeon.

* This statement will be illustrated by reference to two cases which occurred at nearly the same time in the practice of the same surgeon. In March, 1819, M. Dupuytren tied the subclavian artery for axillary aneurism, and the result was in all respects favourable. —See "Leçons orales," &c., t. iv.; and M. Marx in "Repert. général d'anatomie," &c. 1826.

Two or three weeks afterwards the same surgeon, being engaged in performing an operation of the same kind, was compelled to discontinue it for a time in consequence of the sufferings of the patient, and an hour and forty-eight minutes elapsed before the operation was concluded. The patient died of hæmorrhage in four days; and, on examination after death, it was found that the artery had been perforated with the aneurism needle. One of the large nerves and half the artery had been included in the ligature. This case is reported by Dr. Rutherford, R.N., who was present at the operation, in "Edinburgh Med. and Surg. Journal," vol. xvi. 1820.

Before concluding the remarks on the third division of the artery, it should be mentioned that the suprascapular or transverse cervical artery may be met with in the operation, which in other cases may be complicated by the occurrence of a branch, or, however rarely, of branches taking rise beyond the scalenus muscle.

The *second division of the subclavian artery* is the part which rises highest in the neck, and on this account it may be advantageously selected for the application of a ligature when the vessel is difficult of access beyond the muscle. The chief objection to operating on the artery in this situation arises from the contiguity of the large branches. Care is necessary in dividing the scalenus muscle to avoid the phrenic nerve and the internal jugular vein. Moreover, the fact of the entire of the subclavian artery being in apposition with the pleura, except when it rests on the rib, must be borne in mind.

Some difficulty may arise from a change in the position of the artery, as when it lies between the fibres of the anterior scalenus, or when it is in front of that muscle; but such cases are of very rare occurrence, and the knowledge of the fact that the vessel may be thus displaced, will assist the surgeon in the event of difficulty arising from this cause.

Before it reaches the scalenus muscle the left subclavian artery [plate 2] may be said to be inaccessible for the application of a ligature, in consequence of its depth and its close connection with the lung and other structures calculated to create difficulty in an operation, among which may be mentioned the internal jugular and left innominate veins. To the difficulties resulting from the manner of its connection with the parts now named, must be added the danger of performing an operation in the neighbourhood of the large branches.

On the right side, though deeply placed and closely connected with important parts, the first division of the subclavian artery may be tied without extreme difficulty. But inasmuch as the length of the vessel, between its three large branches on the one hand, and the common carotid on the other, ordinarily measures no more than an inch, and often less, there is little likelihood of the operation in question being successfully performed in any case; and the probability of success must be held to be still farther diminished when it is considered that the length of the free part of the artery is sometimes lessened by one of the large branches arising nearer than usual to its commencement.

In order to place a ligature on the portion of the right subclavian artery here referred to, it is necessary to divide by horizontal incisions the three muscles which cover it, together with the layers of fascia between and beneath them [plate 17, fig. 1]. While the muscles are being divided, a branch of the suprascapular artery will probably require to be secured [plate 16]. The position of the inner end of the clavicle and of the trachea, and the effect of pressure with the finger on the circulation in the aneurism or in the limb, will assist the surgeon in finding the artery without dissecting the surrounding parts to an unnecessary and injurious extent —a precaution of importance in all cases. In the farther steps of the operation, the exact position of the internal jugular vein, the vagus nerve and the pleura, are to be well remembered.

The right subclavian artery is occasionally somewhat more deeply placed than usual in the first part of its course: and this occurs when it springs from the left side of the arch, or, more frequently, when it separates from the innominate behind the carotid [plate 20, fig. 4].

SURGICAL ANATOMY OF THE BRACHIAL ARTERY.

In the operation for tying the brachial artery, the known direction of the vessel, and the inner margin of the biceps muscle, chiefly aid in determining its position (p. 382). In consequence of the thinness of the parts which cover the artery, and the position of the basilic and median basilic veins with respect to it, even the integuments must be divided with care. After turning aside the superficial vein, should that be necessary, and dividing the fascia, the median nerve will probably come into view, and the artery will then be readily found. This is the course required under ordinary circumstances. But it may happen that after dividing the fascia it will be necessary to cut through a layer of muscular fibres in order to bring the artery into view [plate 37, figs. 3, 4, 5]. The influence of pressure with the finger, in controlling the circulation, will enable the surgeon to determine if

Fig. 699.

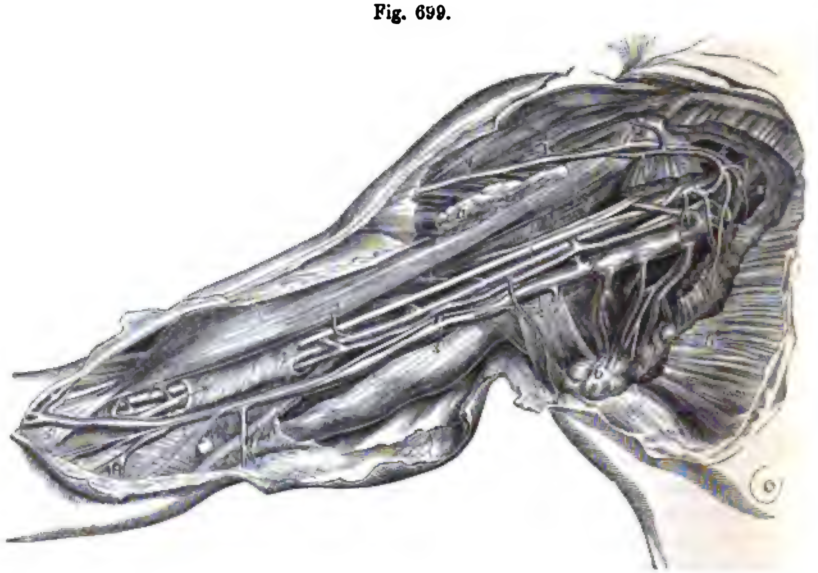


Fig. 699.—Dissection of the Axilla and Inside of the Arm to show the Axillary and Brachial Vessels (from R. Quain). ¼

The greater and lesser pectoral muscles have been divided so as to expose the axillary vessels: *a*, the inserted portion of the pectoralis major; *b*, the pectoral portion; 1, 1, axillary artery; +, +, the median nerve formed by the two portions of the plexus which surround the artery; 1′, placed on a part of the sheath of the brachial vessels, and 1″, on the lower part of the biceps muscle, point to the brachial artery surrounded by its venæ comites; 2, 2, axillary vein; 3, 3, the basilic vein; the upper figure is placed on the triceps muscle, the lower on the fascia near the junction of the ulnar vein: on the basilic vein are seen the ramifications of the internal cutaneous nerve; 4, on the deltoid and 4′, on the clavicular part of the great pectoral muscle, mark the cephalic vein joining the acromio-thoracic and through it the axillary vein; 5, 5, placed on the divided portions of the pectoralis minor, point to the origin and branches of the acromio-thoracic artery; 6, placed on a group of axillary glands, indicates the alar thoracic and subscapular vessels; 7, placed on the trunk of the axillary vein, points by a line to one of the venæ comites of the brachial vein, which being joined by the other higher up passes into the axillary vein: the ulnar nerve is seen passing from below the basilic vein towards the inner condyle; near 1, placed on the coraco-brachialis muscle is seen the musculo-cutaneous nerve before it passes through that muscle.

the vessel be behind the muscular fibres, and will guide him to the place at which they ought to be divided.

Again, as the brachial artery occasionally deviates from its accustomed place in the arm, it is prudent, before beginning an operation on the living body, to be assured of its position by the pulsation. Should the vessel be thus displaced, it has the ordinary coverings of the brachial artery, except at the lower part of the arm, where some fibres of the pronator teres will require to be divided in an operation for securing the vessel.

When the brachial artery is double, or when two arteries are present in the arm, both being usually placed close together, they are accessible in the same operation. The circumstance of one being placed over the fascia (should this very unfrequent departure from the usual arrangement exist) will become manifest in the examination which ought to be made in all cases before an operation is begun. And, as regards the occasional position of one of the two arteries beneath a stratum of muscular fibres, or its removal to the inner side of the arm (in a line towards the inner condyle of the humerus), it need only be added that a knowledge of these exceptional cases will at once suggest the precautions which are necessary, and the steps which should be taken when they are met with.—The foregoing observations have reference to operations on the brachial artery, above the bend of the elbow; the surgical anatomy of the vessel opposite that joint requires a separate notice.

Fig. 700.

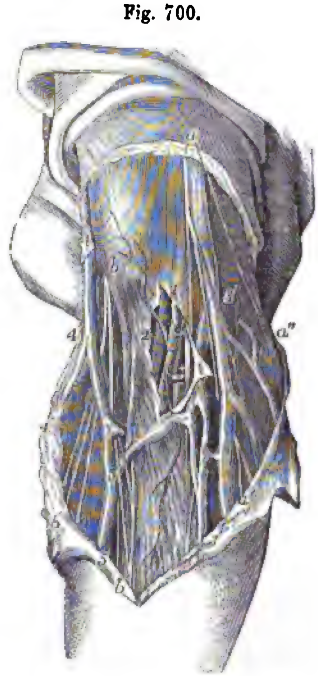


Fig. 700.—Superficial Dissection of the Blood-Vessels at the Bend of the Arm (from R. Quain). ⅓

a, two branches of the internal cutaneous nerve; *a'*, *a'*, the descending twigs of the same nerve; *b*, placed over the biceps near its insertion and close to the external cutaneous nerve; *b'*, anterior twigs of the same nerve accompanying the median vein; 1, placed on the fascia near the bend of the arm, above the place where it has been opened to show the lower part of the brachial artery with its venæ comites, of which one is entire, marked 2, and the other has been divided; +, is placed between this and the median nerve; 3, basilic vein; 3', 3', ulnar veins; 4, cephalic vein; 4', radial vein; 5, 5, median vein; 3', 5, median basilic vein; 4', 5, median-cephalic vein.

At the *bend of the elbow* the disposition of the brachial artery is chiefly, or, at least, most commonly, of interest in a surgical point of view, because of its connection with the veins from which blood is usually drawn in the treatment of disease. The vein (median basilic) which is generally the most prominent and apparently best suited for venesection is commonly placed over the course of the brachial artery, separated from it only by a thin layer of fibrous structure (the expansion from the tendon of the biceps muscle); and under such circumstances, it ought not, if it can be

avoided, to be opened with a lancet, except in a part which is not contiguous to the artery.

If two arteries are present, instead of the ordinary single trunk, they are commonly close together; but it now and then happens that an interval exists between them—one being in the usual situation of the brachial, the other nearer, in different degrees in different cases, to the inner condyle of the humerus. There is on this account an additional reason for precaution when venesection is to be performed; and care is the more necessary as the second artery may be immediately under the vein without the interposition of fascia [plate 41].

SURGICAL ANATOMY OF THE COMMON ILIAC ARTERIES.

The common iliac artery (p. 418), extending in a line from the left side of the umbilicus towards the middle of Poupart's ligament, and being placed at its commencement on a level with the highest part of the iliac crest, may be approached in an operation, by dividing the abdominal muscles to a sufficient extent in the iliac region, and a little above this part of the abdomen. The incisions might be made, beginning about Poupart's ligament, to the outer side of its middle, and running parallel with that structure towards the anterior superior spine of the hip-bone, thence curving for a couple of inches towards the umbilicus. In this way the artery will be approached from below, but, if a tumour extends along the external iliac artery, this plan of operation would be objectionable, for the swelling itself, and, it may be, the adhesion of the peritoneum to its surface, would be sources of serious difficulty. Should the aneurism extend upwards in the abdomen it will be best to approach the artery from the side, or rather from above,—not from below. The essential part of the operation, so far as the abdominal muscles are concerned, is, that they should be divided to the extent of five or six inches at the side of the abdomen, beginning about two inches above the level of the umbilicus and ending lower than the iliac spine, the incision being curved outwards towards the lumbar region. Sir P. Crampton, in an operation to tie this artery, divided the muscles from the end of the lowest rib, straight down nearly to the iliac crest, and thence forward a little above the border of the bone as far as its spine.* This plan is well devised for the object.

The fascia behind the muscles (fascia transversalis) is to be cut through with care, and the peritoneum is to be raised from that and the iliac fascia, as well as from the subjacent membrane (sometimes containing fat) which is interposed between the serous and the fibrous membranes. With the peritoneum the ureter will be raised, as this adheres to it.

The artery will be seen on the last lumbar vertebra; and, on the right side of the body, large veins will be in view in close connection with it, viz., both common iliac veins, and the commencement of the lower vena cava [plate 55]. It will be remembered, that in some cases (without transposition of the viscera, as well as with that condition) the iliac veins are joined on the left instead of the right side; and that in another small class of cases the junction of those veins is delayed, so to say [plate 58, figs. 1, 2, 3]. The effect of either of these conformations of the venous system would be to give to the artery on the left side much more than the usual complication with veins. Lastly, the thin subserous membrane covering the artery is divided without any difficulty to admit the passage of the ligature.

* Med. Chir. Trans., vol. xvi.

The common iliac artery is in most cases of sufficient length to admit of the application of a ligature without much apprehension of secondary hæmorrhage occurring in consequence of insufficiency in this respect. But

Fig. 701.

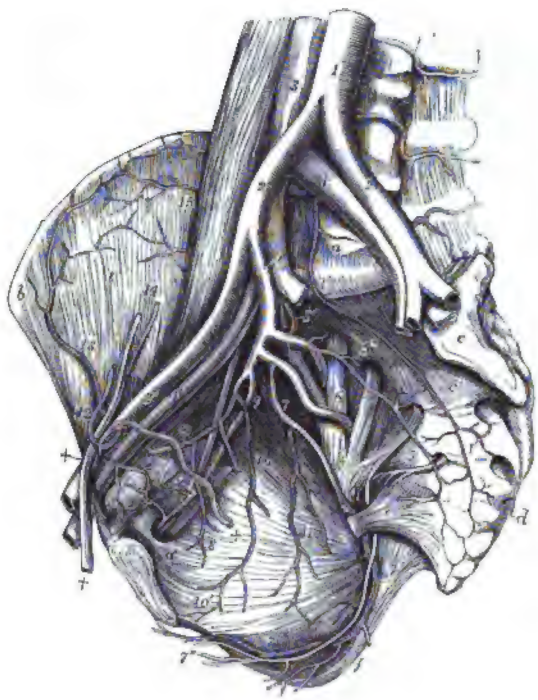


Fig. 701.—View of the right external and internal Iliac Arteries of the Male. ⅓

The viscera of the pelvis have been removed as well as the internal iliac veins. 1, lower part of the abdominal aorta; 1′, middle sacral artery; 2, 2, common iliac arteries; 2′, right external iliac; 3, lower part of the vena cava inferior; 4, 4, common iliac veins; the number on the right points by a line to the right internal iliac artery; 4′, right external iliac vein; 5, placed on the ilio-lumbar nervous trunk, points to the posterior division of the internal iliac artery giving off the gluteal; 5′, ilio-lumbar artery; 5″, lateral sacral artery with branches passing into the anterior sacral foramina; 6, placed on the anterior division of the first sacral nerve, points to the sciatic artery coming from the anterior division of the internal iliac; 7, pudic artery; 7′, the same artery passing behind the spine of the ischium, and proceeding within the ischium and obturator internus muscle, accompanied by the pudic nerve towards the perinæum; towards *f*, inferior hæmorrhoidal branches are given off; 7″, superficial perineal artery and nerve; 8, hypogastric artery, with the obliterated remains of the umbilical artery cut short, and 8′, superior vesical branches rising from it; 9, obturator artery with the corresponding nerve and vein; 9′, the pubic twigs which anastomose with descending twigs of the epigastric artery, and from which, by the enlargement of one of them, the aberrant obturator artery may proceed; 10, inferior vesical; 11, middle hæmorrhoidal vessels rising in this instance from the pudic; 12, epigastric artery winding to the inside of +, +, the vas deferens and spermatic cord; 13, circumflex iliac artery; 14, spermatic artery and vein divided superiorly; 15, twigs of the ilio-lumbar artery proceeding to anastomose with the circumflex iliac.

it has been shown (p. 420) to be in some instances very short—so short that the operation would be inadmissible. In any case in which the common trunk is thus short, it would probably be more prudent to place a ligature on the external iliac and another on the internal iliac, at the origin of each, than to tie the common iliac artery, or the external iliac alone near its commencement.

The surgeon has it in his power to judge of the length of the artery during

the operation, and to determine as to the propriety of tying the one vessel or the other, for the iliac arteries are under his view almost as fully as if dissected. Arteries in other parts of the body are, on the contrary, only seen at the point at which it has been beforehand determined to place the ligature.

SURGICAL ANATOMY OF THE INTERNAL ILIAC ARTERY.

This artery has been tied for aneurism affecting one of its large branches on the back of the pelvis—the gluteal or sciatic (p. 420). It is arrived at by dividing the abdominal muscles before the iliac fossa to a greater extent than is required for exposing the external iliac—in the manner of the operation first mentioned for the common iliac artery. The vein, a large one, is, it will be borne in mind, behind the artery and in contact with it [plate 55]; it is occasionally double [plate 58, fig. 6].

There is some difference in the degree of difficulty that would be experienced in securing the internal iliac artery in different cases. This is owing to the fact, that, when short, (and, as stated before, it often is so,) the artery is placed deeply in the pelvis; whereas, when the length is more considerable, it is accessible above that cavity.

Again, when the artery is very short, [as represented, for instance, in plate 58, fig. 1,] it would probably be more safe to tie the common iliac, or both the external and the internal iliacs at their origin, than to place a ligature on the latter only, close to a strong current of blood.

SURGICAL ANATOMY OF THE EXTERNAL ILIAC ARTERY.

The external iliac artery (p. 431) admits of being tied in a surgical operation at any part except near its upper and lower end; the near neighbourhood of the upper end being excepted on account of the circulation through the internal iliac, and the lower end on account of the common position of the branches (epigastric and circumflex iliac). Occasional deductions from this statement occur in consequence of a branch or branches taking origin near or at the middle of the artery; and as the operator may see such a branch he will avoid placing a ligature very near it.

The incision through the muscles to reach the artery, commencing a little above the middle of Poupart's ligament, may be directed parallel with the ligament upwards and outwards as far as its outer end, where the incision may be curved with advantage for a short space (about an inch) upwards.

This and the other iliac arteries might be operated on by means of straight incisions in a line from the umbilicus to the middle of Poupart's ligament, or a little to the outer side of this line. But the division of the muscles on the fore part of the abdomen is liable to the objection that the peritoneum must be disturbed in front as well as behind; and, moreover, a curved incision has the advantage of giving more room laterally than one which is merely straight.

The muscles and the fascia transversalis being divided, and the peritoneum (to which the spermatic vessels adhere) being raised, the artery is found where the finger of the surgeon, introduced into the wound, begins to descend into the true pelvis, along the border of the psoas muscle.

In contact with the artery will be seen the following structures, each occupying the position already mentioned, viz., lymphatic glands, the circumflex iliac vein, and the external iliac vein [plate 55].

In order to pass the ligature, it is necessary to divide the thin and sometimes resistent subserous membrane, which binds the vessel down to the fascia iliaca.

SURGICAL ANATOMY OF THE FEMORAL ARTERY.

The femoral artery (p. 434) is accessible to the surgeon for the application of a ligature without serious difficulty in its entire length; but as the lower half is deeply placed, the difficulty of reaching this part is greatest, and renders it necessary to divide and disturb the surrounding structures to a greater extent than where the vessel is nearer the surface. For these reasons the upper part of the artery is to be preferred for the performance of the operation adverted to, in all cases in which other circumstances do not control the choice of the surgeon. But the upper part of the femoral artery is not equally eligible for the application of a ligature at all points, in consequence of the position of the branches—an important consideration in the surgical anatomy of this vessel.

Close to the commencement of this artery are two considerable branches (epigastric and circumflex iliac); and between one and two inches lower down the deep femoral branch ordinarily takes its rise. A ligature placed on the arterial trunk in the interval between those branches, that is to say, on the common femoral artery, is in the near neighbourhood of two disturbing causes,—two sources of danger, so near that the prospect of a favourable issue to the operation is, under ordinary circumstances, very small.

Moreover, it has been shown amid the facts detailed before (p. 441), that the origin of the deep femoral is often less than the average distance from Poupart's ligament; and that, not unfrequently, a considerable branch (one of the circumflex arteries) takes its rise from the common femoral artery. When these circumstances are considered, the operation of tying the common femoral artery, or the femoral artery within two inches of its commencement, must be regarded as very unsafe. And it may be added, that the conclusion to which the anatomical facts would lead is fully confirmed by the results of cases in which the operation has been actually performed.

It remains to determine where a ligature applied to the main artery shall be sufficiently distant from the origin of the deep femoral below it, to be free from the disturbing influence of the circulation through that great branch. It has been shown that now and then a case occurs in which the profunda is given off at the distance of from two to three inches below Poupart's ligament—in only a single instance out of a large number of observations did the space referred to amount to four inches.

From the foregoing remarks the inference to be deduced is, that the part of the femoral artery to be preferred for the operation supposed, is at the distance of between four and five inches below the lower margin of the abdominal muscles.

Remarks on the operation.—The position of the artery being determined, and the integument and fat divided, a vein may be met with lying on the fascia, over the course of the artery. The saphenous vein being nearer to the inner side of the limb than the line of incision, is not seen in the operation. The fascia lata, which is now to be divided, has a more opaque appearance over the vessels than over the muscles, for the colour of the latter appears through the membrane. After dividing the fascia, the edge of the sartorius muscle will, in many cases, require to be turned aside; and occa-

sionally this muscle crosses the thigh so directly, that it must be drawn considerably outwards in order to reach the artery [plate 74, fig. 4]. To the exact point at which the sheath of the vessels, and even the fascia should be

Fig. 702.

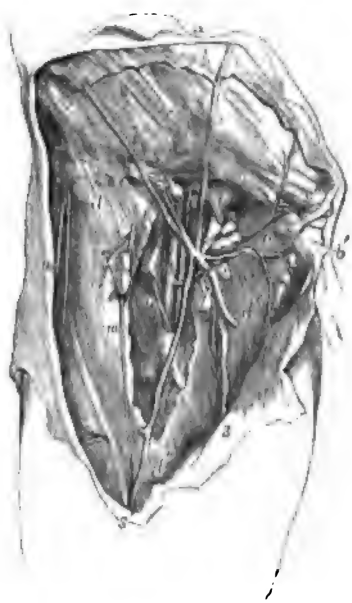


Fig. 702.—Superficial Dissection of the Femoral Vessels, with their smaller Branches in the Right Groin (from R. Quain). ½

a, the integument of the abdomen; *b*, the superficial abdominal fascia; *b'*, the part descending on the spermatic cord; *c*, *c*, the aponeurosis of the external oblique muscle; *c'*, the same near the external abdominal ring; *c''*, the inner pillar of the ring; *d*, the iliac part of the fascia lata; *d'*, the pubic part; *e*, *e*, the sheath of the femoral vessels laid open, the upper letter is immediately over the crural aperture; *e'*, placed on the sartorius muscle partially exposed, points to the margin of the saphenic opening; 1, femoral artery, having the femoral vein 2, to its inner side, and the septum of the sheath shown between the two vessels; 3, the principal saphenous vein; 3', its anterior branch; 4, the superficial circumflex iliac vein and arterial branches to the glands of the groin; 5, the superficial epigastric vein; 6, the external pudic arteries and veins; 7 to 8, some of the lower inguinal glands receiving twigs from the vessels; 9, internal, 10, middle, and 11, external cutaneous nerves.

cut through, the pulsation of the artery will guide the operator. A small nerve may present itself in this part of the operation. The immediate investment of the artery should be opened to the smallest possible extent, and the knife or other instrument should be sparingly used at this stage of the operation; the object being to disturb the artery from its connections, including its nutrient vessels (vasa vasorum), as little as possible, and likewise to avoid wounding any of the small muscular branches which spring from most arteries at irregular intervals. The division of an artery of the size of those last referred to at a distance from the source from which it springs is of little importance. It contracts, and soon ceases to bleed. But when it is divided close to the trunk, blood issues from it as it would if an opening equal in size to the calibre of the little branch were made in the trunk itself.

In order to avoid injuring the vein, which is separated from the artery only by a thin partition of areolar tissue, the point of the aneurism needle, which conveys the ligature, is to be kept close to the artery.

Other veins of occasional occurrence may render increased care necessary, for example, those small branches which cross the artery or course along its surface; or it may be a larger vein—a division of the femoral vein when it is double, or the deep femoral vein when the ligature is applied a little higher than usual [plate 75].

To reach the femoral artery in the middle of the thigh, the depth of the vessel being considerable, the incision through the integuments must be proportionally long. As the sartorius is directly over the vessel, the opera-

tion may be performed by turning the muscle either towards the outer or the inner side of the limb; and the incision would be made, according to the plan adopted, at the inner or the outer margin of the muscle. The

Fig. 703.

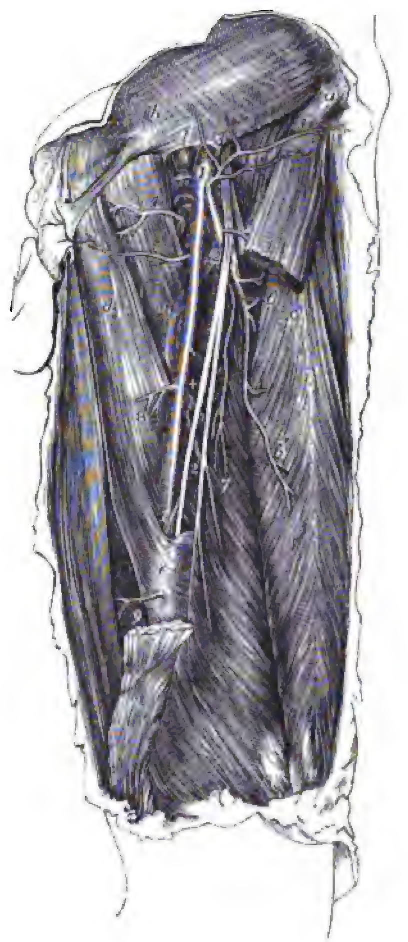


Fig. 703.—DEEP VIEW OF THE FEMORAL ARTERY AND ITS BRANCHES ON THE LEFT SIDE (from R. Quain). ¼

The sartorius muscle has been removed in part, so as to expose the artery inthe middle third of the thigh; *a*, the anterior superior iliac spine; *b*, the aponeurosis of the external oblique muscle near the outer abdominal ring, from which the spermatic cord is seen descending towards the scrotnm; *c*, the upper part of the rectus femoris muscle; *d*, adductor longus; *e*, fibrous sheath of Hunter's canal covering the artery; 1, femoral artery; 1′, femoral vein divided and tied close below Poupart's ligament; 2, profunda femoris artery; 3, anterior crural nerves; 4, internal circumflex branch; 5, superficial pudic branches; 6, external circumflex branch, with its ascending transverse and descending branches separating from it; 6′, twigs to the rectus muscle; 7, branches to the vastus internus muscle; 8, and 9, some of the muscular branches of the femoral.

preferable mode appears to be, to divide the integument on or over the muscle, near its inner margin, so as to arrive directly upon the muscle and draw it outwards, after cutting freely through the investing fascia. The fibrous structure stretched over the vessels from the adductors to the vastus internus muscle being divided, the position of the femoral vein and saphenous nerve are to be kept in view in completing the operation. In the first steps of the operation in this part of the thigh, injury to the long saphenous vein is to be guarded against.

Before concluding the observations on the femoral artery, a very small class of cases claims a word of notice. It has happened (in Sir Charles Bell's case) that the application of a ligature to a femoral artery has not been followed by the usual consequence of cessation of the pulsation in the aneurism; and the uninterrupted continuance of the circulation was found, on examination after death, to be attributable to the circumstance of the artery being double where the ligature was applied, while the two parts became re-united above the tumour. If such a case should again be met with in an opera-

tion, the surgeon, instructed by the case alluded to, and by other examples of the same arrangement of the arteries which have since been observed, might at once, under the guidance of the pulsation, or of the effect of pressure in controlling the circulation through the aneurism, divide the covering of areolar tissue over the second part of the artery, and tie it likewise.

II. SURGICAL ANATOMY OF THE PARTS CONCERNED IN CERTAIN ABDOMINAL HERNIÆ.

Besides the surgical anatomy of the principal arteries, certain parts of the walls of the abdomen and pelvis are to be now considered with reference to surgical operations in which the viscera of those cavities are from time to time concerned.

The walls of the abdomen, when in a healthy state, unaffected by injury, disease, or malformation, retain the viscera within the cavity under all circumstances ; but where certain natural openings exist for the passage of blood-vessels, protrusions of the viscera, constituting the disease named "hernia" or "rupture," are liable to occur under the influence of the compression to which the organs are subjected during the production of efforts. For the replacement of the viscus so protruded, an accurate acquaintance with the structure of the part through which the protrusion takes place is required by the surgeon ; and, on this account, an examination of the seat of the hernia as a surgical region becomes necessary.

Two of the openings by which herniæ escape from the abdomen are situate close together at the groin. One is the canal in the lower part of the broad abdominal muscles, which gives passage in the male to the duct and vessels of the testis (spermatic cord), and in the female to the round ligament of the womb. The second opening exists at the inner side of the large femoral blood-vessels.

Hernial protrusions are likewise found to escape at the umbilicus, in the course of the blood-vessels which occupy that opening in the fœtus, or in the immediate neighbourhood of the opening; and at the thyroid foramen where the obturator vessels and nerve pass downwards to the adductor muscles of the thigh. According to the situation they occupy, these herniæ are named respectively inguinal, femoral, umbilical, and obturator. They will now be separately noticed ; but, inasmuch as the structure of the parts connected with the umbilical and obturator herniæ is by no means intricate, and as, moreover, it is noticed with sufficient detail in text books of practical surgery, it will be unnecessary to refer farther in this work to those forms of hernia.

OF THE PARTS CONCERNED IN INGUINAL HERNIA.

The inguinal hernia, it has been stated above, follows the course of the spermatic cord from the cavity of the abdomen. We shall therefore, before adverting to the hernial protrusions, examine the structure of the abdominal walls in the neighbourhood of the canal in which the cord is placed ; and for this purpose it will be supposed that the constituents of those walls are successively laid bare and everted to such an extent as would be permitted by two incisions made through them, and reaching, one along the linea alba for the length of three or four inches from the pubes, the other, from the upper end of the vertical incision outwards to the superior spine of the hip-bone.

The *superficial fascia* (p. 257) is connected along the fold of the groin

with Poupart's ligament and the upper end of the fascia lata; and, after descending over the spermatic cord into the scrotum, it becomes continuous with the membrane of the same kind which covers the perinæum. Its thickness varies much in different persons, on account of the different quantity of fat contained within its meshes; but in the scrotum the fascia is devoid of fat; as it also is elsewhere towards the internal surface, where its density is at the same time augmented. From the varying thickness of this structure on the abdomen and the scrotum, as well as in different persons, it will be inferred that the depth of incision required to divide it in an operation must vary considerably.

The *superficial vessels* of the groin are encased by the fascia, and are held to separate it into two layers. The vessels which ramify over the inguinal canal and the scrotum are the external pudic and epigastric arteries and veins (p. 437 and 475). The veins, especially the epigastric, are considerably larger than the arteries they accompany. Some of these vessels are wounded in operations performed for the relief of strangulated hernia; but the bleeding from them is small in quantity and rarely requires the application of a ligature or other means to arrest it. The lymphatic glands of the groin (p. 489) admit of being arranged in two sets—one being placed over Poupart's ligament and parallel with that structure; while the other series is upon the upper part of the thigh at its middle, about the saphenous opening in the fascia lata.

When the superficial fascia is removed, the aponeurosis of the *external oblique muscle* (p. 249) is in view, together with, in the male body, the spermatic cord, in the female body the round ligament of the uterus, which emerge from an opening close to the outer side of the pubic spine. The lowest fibres of the aponeurosis, as they approach the pubes, become separated into two bundles which leave an interval between them for the passage of the cord or round ligament. One of the bands, the upper one and the smaller of the two, is fixed in front of the symphysis of the pubes; and the lower band, which forms the lower margin of the aponeurosis, being stretched between the anterior superior iliac spine and the pubes, is named Poupart's ligament, or the femoral arch. This latter tendinous band has considerable breadth. It is fixed at the inner end to the spine of the pubes, and, for some space outside that process of the bone, to the pectineal ridge. In consequence of the position of the pectineal ridge at the back part of the bone, the ligament is tucked backwards; and its upper surface affords space for the attachment of the other broad muscles, at the same time that it supports the spermatic cord. Poupart's ligament does not lie in a straight line between its two fixed points; it curves downwards, and with the curved border the fascia lata is connected. It is owing to the last-mentioned fact that the so-named ligament, together with the rest of the aponeurosis of the external oblique, is influenced by the position of the thigh, being relaxed when the limb is bent, and the converse. Moreover, the change of the position of the limb exercises a corresponding influence on the state of the other structures connected with Poupart's ligament.

The interval left by the separation of the fibres of the aponeurosis above referred to, is named the *external abdominal ring*, and the two bands by which it is bounded are known as its *pillars* or *columns*. The space is triangular in shape, its base being the crest of the pubes, while the apex is at the point of separation of the two columns. The size of the ring varies considerably in different bodies;—in one case its sides will be found closely applied to the spermatic cord; while, in another, on the contrary, the space

is so considerable as to be an obvious source of weakness to the abdominal parietes. It is usually smaller in the female than in the male body.

Fig. 704.

Fig. 704.—The Aponeurosis of the External Oblique Muscle and the Fascia Lata.

1, the internal pillar of the abdominal ring; 2, the external pillar of the same (Poupart's ligament); 3, transverse fibres of the aponeurosis; 4, pubic part of the fascia lata; 5, the spermatic cord; 6, the long saphenous vein; 7, fascia lata.

Between the pillars of the abdominal ring is stretched a thin fascia, named, from that circumstance, "intercolumnar;" and a thin diaphanous membrane prolonged from the edges of the opening affords a covering (fascia spermatica) to the spermatic cord and the tunica vaginalis testis. The cord in passing through the ring lies over the outer pillar.

Fig. 705.

Fig. 705.—Deeper Dissection of the Abdominal Wall in the Groin.

The aponeurosis of the external oblique muscle having been divided and turned down, the internal oblique is brought into view with the spermatic cord escaping beneath its lower edge; 1, aponeurosis of the external oblique; 1′, lower part of the same turned down; 2, internal oblique muscle; 3, spermatic cord; 4, saphenous vein.

Internal oblique muscle (p. 250).—After removing the aponeurosis of the external oblique, this muscle is laid bare. The lower fibres are thin and often of a pale colour. Immediately above Poupart's ligament the outer part is muscular, the inner part tendinous. The spermatic cord, when about to escape at the external abdominal ring, passes beneath the fleshy part of the muscle. The fibres in this situation varying considerably in direction from those of the rest of the muscle, pass inwards from Poupart's ligament at first nearly parallel with that structure; and, becoming tendinous, they join with the tendon of the transversalis.

Fig. 706.

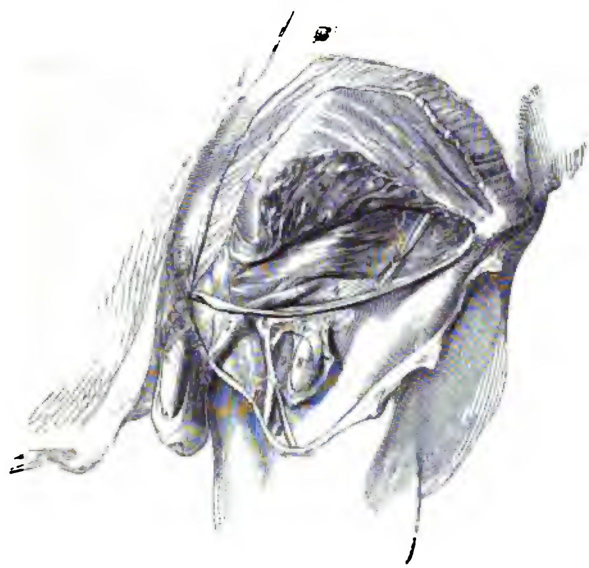


Fig. 706.—The Inguinal Canal and Femoral Sheath fully exposed.

After the removal of the lower part of the external oblique (with the exception of a small slip including Poupart's ligament), the lower portion of the internal oblique has been raised, and thereby the transversalis muscle and fascia have been brought into view. The femoral artery and vein are seen to a small extent, the fascia lata having been turned aside and the sheath of the blood-vessels laid open. 1, external oblique muscle; 2, internal oblique; 2′, part of same turned up; 3, transversalis muscle. Upon the last-named muscle is seen a branch of the circumflex iliac artery, with its companion veins; and some ascending tendinous fibres are seen over the conjoined tendon of the two last-named muscles; 4, transversalis fascia; 5, spermatic cord covered with the infundibuliform fascia from the preceding. 6, upper angle of the iliac part of fascia lata; 7, the sheath of the femoral vessels; 8, femoral artery; 9, femoral vein; 10, saphenous vein; 11, a vein joining it.

Transversalis muscle.—This muscle (p. 253) does not, in general, extend down as far as the internal oblique; so that the latter being removed, an interval is observable between the edge of the transversalis and Poupart's ligament, in which the transversalis fascia comes into view; and in which the spermatic cord is seen after having penetrated that fascia. The lower edge of the muscle is commonly close above the opening for the cord in the subjacent membrane, while its tendon curves to the inner side; so that

the margin of the muscle with its tendon has a semicircular direction with respect to the aperture.

The tendinous fibres in which the fleshy parts of the two preceding muscles end, are connected together so as to form one layer, which is named the "conjoined tendon of the internal oblique and transverse muscles." This tendon is fixed to the crest of the pubes in front of the rectus muscle, and likewise to the pectineal ridge. It is thus behind the external abdominal ring, and serves to strengthen the wall of the abdomen where it is weakened by the presence of that opening.

A band of tendinous fibres, directed upwards and inwards over the conjoined tendon in a triangular form gives additional strength to the abdominal wall in the same situation, but the fibres of this structure are often very indistinct.

Where the spermatic cord is in apposition with the preceding muscle, the cremaster muscle of the testis descends over it. The fibres which compose this muscle are, from their colour, more easily distinguished than the other investments of the cord; and this is especially the case in robust persons; or when they are hypertrophied, as sometimes happens in cases of long-standing hernia. The outer part of the cremaster is much larger than the portion connected with the pubes; and the latter is sometimes absent (p. 253).

When observed in different bodies the lower parts of the internal oblique and transverse muscles present some differences in their physical characters as well as in the manner in which they are disposed with respect to the spermatic cord. Thus:—

a. The transversalis, in some cases, is attached to but a small part of Poupart's ligament, and leaves, therefore, a larger part of the abdominal wall without its support. On the other hand, that muscle may be found to extend so low down as to cover the internal abdominal ring together with the spermatic cord, for a short space. Not infrequently the fleshy fibres of the two muscles are blended together as well as their tendons.

b. Cases occasionally occur in which the spermatic cord, instead of escaping beneath the margin of the internal oblique, is found to pass through the muscle, so that some muscular fibres are below as well as above it. And examples of the transversalis being penetrated by that structure in the same manner are recorded.*

c. In his latest account of the structure of these parts Sir A. Cooper described the lower edge of the transversalis as curved all round the internal ring and the spermatic cord. "But the lower edge of the transversalis has a very peculiar insertion, which I have hinted at in my work on hernia. It begins to be fixed in Poupart's ligament, almost immediately below the commencement of the internal ring, and it continues to be inserted behind the spermatic cord into Poupart's ligament as far as the attachment of the rectus."† With this disposition of its fibres, the muscles would, in the opinion of the last-cited authority, have the effect of a sphincter, in closing the internal ring, and would thus tend to prevent the occurrence of hernia. But the principal object with which the attention of surgeons has been fixed on the muscles in this situation, is in order to account for the active strangulation of hernial protrusions at the internal abdominal ring, and in the inguinal canal.

Fascia transversalis.—This membrane is described as part of the general lining of the abdominal walls (p. 258). Closely connected with the transversalis muscle by means of the areolar tissue interposed between the fleshy fibres of the muscle, it is united below to the posterior edge of Poupart's

* Recherches Anatomiques sur les Hernies, &c., par J. Cloquet, p. 18 and 23. Paris, 1817. Inguinal and Femoral Herniæ, by G. J. Guthrie, plate I. London, 1833.

† Observations on the Structure and Diseases of the Testis, second edition, p. 36. Ed. by Bransby B. Cooper, F.R.S. London, 1841.

ligament, there joining with the fascia iliaca; and on the inner side it blends with the conjoined tendon of the internal oblique and transversalis muscles, as well as with the tendon of the rectus. The fascia possesses very different degrees of density in different cases; in some being little more than a loose areolar texture, while in others it is so resistent at the groin—towards which part it increases in thickness, and especially at the lower side of the internal abdominal ring—that it is calculated to afford material assistance to the muscles in supporting the viscera. By an oval opening in this membrane the spermatic cord, or the round ligament of the womb, begins its course through the abdominal parietes. This opening, named the *internal abdominal ring*, is opposite the middle of Poupart's ligament, and usually close above that structure, but occasionally at a distance of three or four lines from it. Its size varies a good deal in different persons, and is considerably greater in the male than the female. From the edge of the ring a thin funnel-shaped elongation (infundibuliform fascia; fascia spermatica interna, Cooper), is continued over the vessels of the spermatic cord.

Epigastric Artery.—The position of this vessel is one of the most important points in the anatomy of the inguinal region, from the close connection which it has with the different forms of inguinal hernia and with the femoral hernia. Accompanied by two veins (in some instances by only one) the vessel ascends under cover of the fascia last described obliquely to the rectus muscle, behind which it then proceeds to its ultimate distribution (p. 432). In this course the artery runs along the inner side of the internal abdominal ring—close to the edge of the aperture, or at a short interval from it. The vessels of the spermatic cord are therefore near to the epigastric artery; and the vas deferens, in turning from the ring into the pelvis, may be said to hook round it.

The *Inguinal Canal.*—This channel, by which the spermatic cord passes through the abdominal muscles to the testis, begins at the internal abdominal ring, and ends at the external one. It is oblique in its direction, being parallel with and immediately above the inner half of Poupart's ligament; and it measures two inches in length. In front the canal is bounded by the aponeurosis of the external oblique muscle in its whole length, and at the outer end by the fleshy part of the internal oblique also; behind it, is the fascia transversalis, together with, towards the inner end, the conjoined tendon of the two deeper abdominal muscles. Below, the canal is supported by the broad surface of Poupart's ligament, which separates it from the sheath on the large blood-vessels descending to the thigh, and from the femoral canal at the inner side of those vessels.

The spermatic cord, which occupies the inguinal canal, is composed of the arteries, veins, lymphatics, nerves, and excretory duct (vas deferens) of the testis, together with a quantity of loose areolar tissue mixed up with those parts. The direction of the vessels just enumerated requires notice. The artery and vein incline outwards from the lumbar part of the vertebral column to reach the internal abdominal ring, where, after being joined by the vas deferens as it emerges from the pelvis, they change their course, inclining inwards along the inguinal canal; at the end of which they become vertical. There are thus repeated alterations in the direction of the vessels; and while at the beginning and ending all are close to the middle line of the body, they are considerably removed from that point where they come together to emerge from the abdominal cavity.

The coverings given from the constituent parts of the abdominal wall to the spermatic cord and the testis, namely, the cremasteric muscular fibres

with the two layers of fascia (the infundibuliform and spermatic fasciæ) between which those fibres are placed, are very thin in their natural state; but they may be readily distinguished in a surgical operation from the investing superficial fascia, by their comparative density and the absence of fat.

In order to examine the *peritoneum* at the groin, it will be best to divide that membrane with the abdominal muscles by two incisions drawn from the umbilicus—one to the hip-bone, the other to the pubes. The flap thus formed being held somewhat outwards, and kept tense, a favourable view will be obtained of the two fossæ (*inguinal fossæ* or *pouches*) with the intervening crescentic fold. This fold is formed by the cord remaining from the obliterated umbilical artery, which, being shorter than the outer surface of the serous sac, causes this to project inwards; and as the length of the cord differs in different cases, so likewise do the size and prominence of the peritoneal fold vary accordingly.

The lowest part of the outer fossa will be generally found opposite to the entrance into the internal abdominal ring and the femoral ring, while the inner one corresponds with the situation of the external abdominal ring. But the cord representing the umbilical artery, which, it has been stated, causes the projection of the serous membrane into a fold, does not uniformly occupy the same position in all cases. Most frequently it is separated by an interval from the epigastric artery, while in some cases it is immediately behind that vessel. There is necessarily a corresponding variation in the extent of the external peritoneal fossa. This fact will find its practical application when the internal form of inguinal hernia is under consideration.

Between the peritoneum and the fascia lining the abdominal muscles is a connecting layer of areolar structure, named the *subserous areolar membrane*. A considerable quantity of fat is in some cases found in this membrane.

The relative position of some of the parts above referred to may be here conveniently stated, by means of measurements, made by Sir A. Cooper, and adopted after examination by J. Cloquet. But as the distance between given parts varies in different cases, the following measurements must be regarded only as a general average:—

	MALE.	FEMALE.
From the symphysis of the pubes to the anterior superior spine of the ilium . . .	$5\frac{1}{2}$ inches. ..	6 inches.
From the same point to the spine of the pubes . .	$1\frac{1}{8}$,, ...	$1\frac{3}{8}$,,
,, to the inner part of the external abdominal ring	$0\frac{5}{8}$,, ...	1 ,,
,, to the inner edge of the internal abdominal ring	3 ,, ...	$3\frac{1}{4}$,,
,, to the epigastric artery on the inner side of the internal abdominal ring .	$2\frac{3}{4}$,, ...	$2\frac{5}{8}$,,

From the preceding account of the structure of the abdominal wall at the groin, it will be inferred that the defence against the protrusion of the viscera from the cavity is here weaker than at other parts. The external oblique muscle and the fascia transversalis are perforated, while the two intervening muscles are thinner than elsewhere, and more or less defective. To this it must be added that the viscera are impelled towards the same part of the abdomen by the contraction of the diaphragm and the other abdominal muscles in the production of efforts to overcome

resistance; and these are the circumstances under which protrusions actually take place.

INGUINAL HERNIÆ.

The protrusions of the viscera, or herniæ, which occur in the course of the inguinal canal, are named "inguinal." Of this form of the disease two varieties are recognised: and they are distinguished according to the part of the canal which they first enter into, as well as by the position they bear with respect to the epigastric artery. Thus, when the hernia takes the course of the inguinal canal from its commencement, it is named *oblique*, because of the direction of the canal, or *external*, from the position its neck bears with respect to the epigastric artery. On the other hand, when the protruded part, without following the length of the canal, is forced at once through its termination, *i. e.* through the external abdominal ring, the hernia is named, from its course, *direct*, or, from its relation to the epigastric artery, *internal*. In these, the two principal varieties of inguinal hernia, there are some modifications which will be adverted to in the special notice of each.

Oblique inguinal hernia.—In the common form of this hernia the protruded viscus carries before it a covering of peritoneum (the *sac* of the hernia), derived from the outer fossa of that serous membrane; and in passing along the inguinal canal to the scrotum, it is successively clothed with the coverings given to the spermatic vessels from the abdominal parietes. The hernia and its sac lie directly in front of the vessels of the spermatic cord (the intestines and the peritoneum having the same position relatively to those vessels in the abdomen); but when the disease is of long standing, the vessels may be found to be separated from each other, and pressed more or less towards the side or even the fore part of the sac, under the influence of the weight of the tumour. The hernia does not extend below the testis, even when it attains large size. That it does not is owing, doubtless, to the intimate connection which the coverings of the cord have with the tunica vaginalis testis.

When the hernia does not extend beyond the inguinal canal, it is distinguished by the name *bubonocele:* and when it reaches the scrotum, it is commonly named from that circumstance *scrotal* hernia.

There are two other varieties of oblique inguinal hernia, in which the peculiarity depends on the condition of the process of peritoneum that accompanies the testis when this organ is moved from the abdomen. In ordinary circumstances the part of the peritoneum, connected immediately with the testis, becomes separated from the general cavity of that serous membrane by the obliteration of the intervening canal; and the hernial protrusion occurring after such obliteration has been completed, carries with it a distinct serous investment—the sac. But if the hernia should be formed before the process of obliteration is begun, the protruded part is then received into the cavity of the tunica vaginalis testis, which serves in the place of its sac. In this case the hernia is named *congenital* (hernia tunicæ vaginalis,—Cooper). It is thus designated, because the condition necessary for its formation usually exists only about the time of birth; but the same variety of the complaint is occasionally found to be first formed in the adult, obviously in consequence of the tunica vaginalis remaining unclosed,—still continuous with the peritoneum. The congenital hernia, should it reach the scrotum, passes below the testis; and this organ being imbedded in the protruded

viscus, a careful examination is necessary in order to detect its position. This peculiarity serves to distinguish the congenital from the ordinary form of the disease.

Fig. 707.

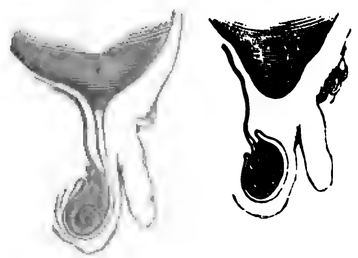


Fig. 707.—Diagrams of a part of the Peritoneum and the Tunica Vaginalis Testis.

In the first, A, the serous investment of the testis is seen to be an elongation from the peritoneum; while in the second, B, the two membranes are shown distinct from each other. 1, the peritoneal cavity; 2, the testis.

To the second variety of inguinal hernia, in which the distinguishing character depends on the state of the tunica vaginalis testis, the name "infantile" has been applied (Hey). The hernia in this case is covered with a distinct sac, the peculiarity consisting in the circumstance of the rupture with its sac being invested by the upper end of the tunica vaginalis. The relative position of the two serous membranes (the hernial sac and the tunica vaginalis) may be accounted for by supposing the hernia to descend when the process of the peritoneum, which accompanies the testis from the abdomen, has been merely closed at the upper end, but not obliterated for any length. As the tunica vaginalis at this period extends upwards to the wall of the abdomen, the hernia, in its descent, soon meets that membrane and becomes invested by it. The exact mode of the investment has not yet been clearly made out by dissection. It may be that the hernia passes behind the upper end of the large serous tunic of the testis, which then laps round the sac from before, or that the tunica vaginalis is inverted from above so as to receive the hernia in a depression. But the fact most material for the surgeon is fully ascertained—namely, that during an operation in such a case, the hernial sac is met with only after another serous bag (the tunica vaginalis testis) has been divided. The peculiarity here described has been repeatedly found present in the recently-formed hernia of grown persons. The term infantile, therefore, like congenital, has reference to the condition of certain parts, rather than to the period of life at which the disease is first formed.

In the female, oblique inguinal hernia follows the course of the round ligament of the uterus along the inguinal canal, in the same manner as in the male it follows the spermatic cord. After escaping from the external abdominal ring, the hernia lodges in the labium pudendi. The coverings are the same as those in the male body, with the exception of the cremaster, which does not exist in the female: but it occasionally happens that some fibres of the internal oblique muscle are drawn down over this hernia in loops, so as to have the appearance of a cremaster (Cloquet).

A strictly congenital inguinal hernia may occur in the female, the protruded parts being received into the little diverticulum of the peritoneum (canal of Nuck), which sometimes extends into the inguinal canal with the round ligament. But as this process of the peritoneum, in such circumstances, would probably not differ in any respect from the ordinary sac, there are no means of distinguishing a congenital hernia in the female body.

Direct inguinal hernia (internal: ventro-inguinal).—Instead of following the whole course of the inguinal canal, in the manner of the hernia above described, the viscus in this case is protruded from the abdomen to the groin directly through the lower end of the canal, at the external abdominal ring; and at this point the two forms of hernia, if they co-existed, would come together. At the part of the abnominal wall through which the direct inguinal hernia finds its way, there is recognised on its posterior aspect a triangular interval, the sides of which are formed by the epigastric artery, and the margin of the rectus muscle, and the base by Poupart's ligament. It is commonly named the triangle of Hesselbach. Through this space the hernia is protruded, carrying before it a sac from the internal fossa of the peritoneum; and it is in general forced onwards directly into the external abdominal ring.

Fig. 708.

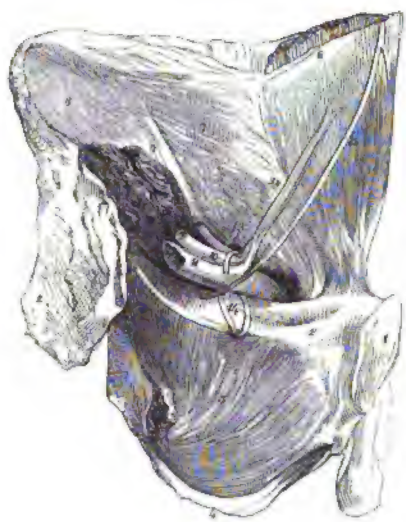


Fig. 708.—INTERNAL VIEW OF THE VESSELS RELATED TO THE GROIN.

A portion of the wall of the abdomen and the pelvis is here seen on the posterior aspect, the os innominatum of the left side and the soft parts connected with it having been removed from the rest of the body. 1, symphysis of the pubes; 2, irregular surface of the hip-bone which has been separated from the sacrum; 3, ischial spine; 4, ischial tuberosity; 5, obturator internus; 6, rectus, covered with an elongation from 7, fascia transversalis; 8, fascia iliaca covering the iliacus muscle; 9, psoas magnus cut; 10, iliac artery; 11, iliac vein; 12, epigastric artery and its two accompanying veins; 13, vessels of the spermatic cord, entering the abdominal wall at the internal ring. The ring was in this case of small size; 14, two obturator veins; 15, the obliterated umbilical artery. The cord, it will be remembered, is not naturally in contact with the abdominal parietes in this situation.

The coverings of this hernia, taking them in the order in which they are successively applied to the protruded viscus, are the following:—The peritoneal sac and the subserous membrane which adheres to it, the fascia transversalis, the tendon common to the internal oblique and transverse muscles, and the intercolumnar (external spermatic) fascia derived from the margin of the external abdominal ring, together with the superficial fascia and the integuments.

With respect to one of the structures enumerated, namely, the common tendon of the two deeper muscles, considerable variety exists as to its disposition in different cases. In place of being covered by that tendon, the hernia may be found to pass through an opening in its fibres, or to escape beneath it. Cremasteric muscular fibres are met with (rarely, however,) upon this hernia.

The spermatic cord is commonly placed behind the outer part of the direct inguinal hernia, especially at the external abdominal ring. It is here that the hernia and the cord in most cases first come together; and

their relative position results from the points at which they respectively pass through the ring, the former being upon the crista of the pubes,

Fig. 709.

Fig. 709.—A Direct Inguinal Hernia on the Left Side, covered by the Conjoined Tendon of the Internal Oblique and Transverse Muscles.

1, aponeurosis of the external oblique; 2, internal oblique turned up; 3, transversalis muscle; 4, fascia transversalis; 5, spermatic cord; 6, the hernia. A small part of the epigastric artery is seen through an opening made in the transversalis fascia.

while the latter drops over the outer pillar of the opening. The hernial sac is not, however, in this case (as the sac of the external form of the disease is) in contact with the vessels of the cord. The investments given from the fascia transversalis to those vessels and to the hernia respectively, are interposed.

But the point at which the internal inguinal hernia passes through the

Fig. 710.

Fig. 710.—A Small Oblique Inguinal Hernia, and a Direct One on the Right Side.

A little of the epigastric artery has been laid bare, by dividing the fascia transversalis immediately over it. 1, tendon of the external oblique; 2, internal oblique turned up; 3, transversalis; 4, its tendon (the epigastric artery is shown below this number); 5, the spermatic cord (its vessels separated); 6, a bubonocele; 7, direct hernia protruded beneath the conjoined tendon of the two deeper muscles, and covered by an elongation from the fascia transversalis.

triangular space above described, as marked on the posterior aspect of the abdominal wall, is subject to some variation. Instead of pushing directly through the external abdominal ring, (the most frequent position), the hernia occasionally enters the inguinal canal nearer to the epigastric artery, and passing through a portion of the canal to reach the external ring, has therefore a certain degree of obliquity. This change in position may coincide with a change of the peritoneal fossa, which furnishes the hernial sac

—a change, namely, from the internal fossa to the external one. The alteration of the fossa does not, however, in all cases coincide with a change in the position of the hernia; for the cord remaining from the obliteration of the umbilical artery, (which separates the fossæ,) instead of crossing behind the triangle of Hesselbach so as to leave room at either side of it for a hernia to penetrate that space, lies, it has been already stated, sometimes directly behind the epigastric artery: — indeed, according to the observations of Cloquet, it is most frequently in this position;* and when the cord in question is so placed, the hernia, whatever may be its position in the triangle of Hesselbach, can occupy only the internal peritoneal fossa. The inference, however, most important in a practical or surgical point of view, to be drawn from the varying position of the neck of the internal hernia, has reference not to the cord just alluded to, but to the epigastric artery—*i. e.* to the greater or less distance of the neck of the sac from that vessel.

The investments of the internal hernia are likewise liable to be influenced by the position at which it penetrates the abdominal wall. It is in all likelihood when the protrusion occurs outside the ordinary situation, that the hernia escapes beneath the conjoined tendon of the two deeper muscles. It is, moreover, under the same circumstances that the hernia is more directly in front of the spermatic cord, and that the cremasteric fibres are among its investments. (Ellis.)

The internal inguinal hernia is very rarely met with in *the female*. In the single example of the disease observed by Richard Quain, as well as in the cases (a very small number) found recorded in books, the hernia, though not inconsiderable in size, was still covered with the tendon of the external oblique muscle.†

Distinctive diagnosis of oblique and direct inguinal herniæ.—The following circumstances, which are brought together from the facts detailed in the preceding pages, or are inferences from those facts, will serve to distinguish the two forms of the disease from one another. The oblique hernia, when recently formed, is elongated and narrow at its upper part, being restrained by the tendon of the external oblique muscle. It is, however, attended with a degree of fulness in the inguinal canal, as well as tenderness upon pressure being made over the canal. After passing through the external abdominal ring, it is observed to be directly in front of the spermatic cord. The direct hernia, when of small size, is globular; it is protruded more immediately over the pubes; causes no fulness or tenderness in the canal; and the spermatic cord is usually behind its outer side. But the distinction between the two herniæ admits of being made only when the disease is recent and the tumour moderate in size; for when oblique inguinal hernia is of long standing, and has attained considerable

* Recherches, &c., p. 39, note.

† See "Treatise on Ruptures," by Mr. Lawrence, 4th edit. p. 213, and an essay by M. Velpeau in "Annales de Chirurgie Française et étrangère," tom. i. p. 352.

M. Velpeau, in the essay just referred to, proposes to recognise three varieties of internal hernia, viz., 1. the ordinary form which passes straight through the external abdominal ring; 2. an outer oblique variety, which passes through a part of the inguinal canal; and 3, an inner oblique one, which entering the abdominal wall close to the edge of the rectus muscle, is directed outwards in order to reach the opening in the external oblique muscle. The first two forms adverted to by M. Velpeau have been described in the text. With respect to the third variety or class sought to be introduced by that surgeon, it should be observed that he seems to have been led to propose it by the observation of a single case—an example of internal hernia in the female.

size, the obliquity of the inguinal canal no longer remains,—the internal ring being enlarged and brought inwards opposite the external one,—while at the same time the epigastric artery, borne inwards by the hernia, curves along the inner side of the sac. Under this change, the oblique hernia assumes the appearance of one primarily direct.

Operations for the relief of inguinal hernia.—This account of the disposition of the parts connected with the different forms of inguinal hernia may be concluded by a brief statement of the application of the anatomical facts in practical surgery, either in simply replacing the hernial protrusion, or in the operation required to attain that object when the hernia is otherwise irreducible. In the efforts to effect the replacement of the protruded parts (the taxis), it is to be borne in mind that the abdominal muscles, which, in most cases, are the sole obstacle to the attainment of that end, become relaxed to some extent by flexing the thigh and inclining the trunk forwards. The direction, too, which the protruded part follows through the abdominal walls, ought to influence the direction given to the pressure required in restoring it.

When the operation required to set free the constriction which prevents the restoration of the protruded viscus to the abdomen is undertaken, the parts covering the hernia or a portion of it at the upper end, are to be divided, so as to allow the introduction of a knife beneath the "stricture"; and this (the stricture) will be found at the external ring, or, more frequently, at the internal one. To accomplish the object, the tendon of the external oblique is to be laid bare by an incision beginning somewhat above the upper end of the hernia, and extending downwards below the external ring. If, on examination, the stricture should be ascertained to be at the last-named opening, the division of a few fibres of its circumference will allow a sufficient dilatation for the replacement of the hernia; but if, as generally happens, the seat of the stricture should prove to be higher up,—in the inguinal canal or at the internal ring,—the aponeurosis of the external oblique is to be cut through over the canal, and the lower edge of the internal muscles, one of which commonly constitutes the stricture, is then to be divided on a director insinuated beneath them.

In the operation indicated in the last paragraph, the sac of the hernia is supposed to be left unopened,—the course which it is best to adopt when the stricture is external to that membrane. Occasionally, however, it happens that the sac itself is the cause of the constriction. When this is the case, or when from some other reason the surgeon is unable, after such an operation as that above noticed, to replace the hernia, it becomes necessary to lay the sac open, in order to divide the constriction at its neck. When the incision required in the last-mentioned step of the operation is being made, the epigastric artery is not to be overlooked. From the position that vessel holds with respect to the oblique and direct forms of hernia respectively, it necessarily follows that an incision outwards through the neck of the sac, in the former variety of the disease, and inwards in the latter, would be free from risk on account of the artery; but, inasmuch as the oblique hernia is liable, in time, to assume the appearance of one primarily direct, and a want of certainty as to the diagnosis must, on this account, exist in certain cases,—as, moreover, it is advantageous to pursue one course which will be applicable in every case,—the rule generally adopted by surgeons in all operations for inguinal herniæ, is to carry the incision through the neck of the sac directly upwards from its middle.

OF THE PARTS CONCERNED IN FEMORAL HERNIA.

The hernia distinguished as 'femoral' leaves the abdomen at the groin, under the margin of the broad abdominal muscles, and upon the anterior border of the hip-bone, immediately at the inner side of the large femoral blood-vessels. After passing downwards for about an inch or less, the hernia turns forwards to the fore part of the thigh at the saphenous opening in the fascia lata; and when it has reached this point the swelling may be felt and seen.

The muscles of the abdomen, beneath the edge of which the femoral hernia escapes, are represented by the aponeurotic band of the external oblique muscle, which is commonly known as Poupart's ligament, but which, in connection with the femoral hernia, is named the *femoral* or *crural arch*. Extending from the anterior superior iliac spine to the pubes, this band widens at its inner end, and, inclining or folding backwards, is fixed to a part of the pectineal line, as well as to the pubic spine of the hip-bone. The small triangular portion attached to the pectineal line is known as Gimbernat's ligament (Hey). The outer edge of this part is concave and sharp; with other structures, to be presently described, it forms the inner boundary of the aperture through which the hernia descends. The breadth and strength of Gimbernat's ligament vary in different bodies, and with its breadth the size of the opening which receives the hernia will likewise vary.

The space comprised between the femoral arch and the excavated margin of the pelvis is occupied by the conjoined psoas and iliacus, with the anterior crural nerve between those muscles, and the external iliac artery and vein at their inner side. Upon these structures the fascia which lines the abdomen is so arranged as to close the cavity against the escape of any part of the viscera, except at the inner side of the blood-vessels. But the arrangement of the parts situate thus deeply (towards the cavity of the abdomen) will be most conveniently entered upon after those nearer to the surface shall have been examined. To this examination we now proceed.

The general disposition of the *superficial fascia* met with on removing the common integument from the groin has been described (p. 292). In connection with the present subject it will be enough to mention the following facts. The deeper layer of this structure adheres closely to the edge of the saphenous opening, and the careful removal of it is necessary in order adequately to display that aperture. Where it masks the saphenous opening, the deep layer of the superficial fascia supports some lymphatic glands, the efferent vessels of which pass through it; and the small portion of the membrane so perforated is named the *cribriform fascia*. The superficial and the deep fasciæ adhere together along the fold of the groin likewise; and this connection between the two membranes serves the purpose, at least, of drawing the integument the more evenly into the fold of the groin, when the limb is bent at the hip-joint.

By Scarpa the deep layer of the superficial fascia which covers the abdomen was described as an emanation from the fascia lata, extended upwards over the external oblique muscle.* But different modes of viewing the continuity of such structures depend very much on the manner of conducting the dissection. In the present case, for example, the fascia may be said to proceed from above or from below, according as the parts are dissected from the abdomen downwards, or from the thigh upwards.

* A Treatise on Hernia, translated by Wishart. p. 247.

Such difference, however, is no more than a verbal one, the material fact being merely that the two membranes are connected together along the groin.

The separation of the *fascia lata* into two parts at the saphenous opening, and the position and connections of each part, having been described in detail, only a few points in the arrangement of this membrane will be noticed in this place. At the lower end of the saphenous opening the iliac division of the fascia is continuous with the pubic by a well-defined curved margin immediately above which the saphenous vein ends; above the opening a pointed cornu (falciform process—Burns *) of the same portion of the fascia extending inwards in connection with the femoral arch reaches Gimbernat's ligament; and in the interval between the two points now referred to (*i. e.*, from the upper to the lower end of the saphenous opening), the iliac portion of the fascia lata blends with the subjacent sheath of the femoral vessels as well as with the superficial fascia. The pubic part of the fascia covers the pectineus muscle, and is attached to the pectineal ridge of the hip-bone. Immediately below the femoral arch the iliac and pubic portions lie one before, the other behind, the femoral blood-vessels and their sheath: they occupy the same position with respect to the femoral hernia.

Fig. 711.

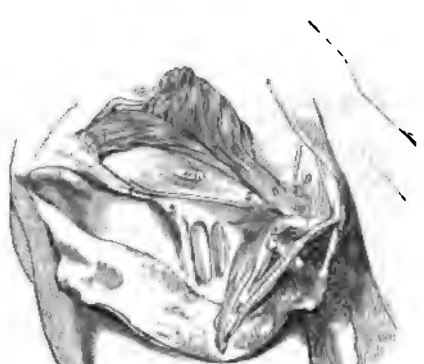


Fig. 711.—The Groin of the Right Side dissected so as to display the Deep Femoral Arch.

1, the outer part of the femoral arch; 1', part of the tendon of the external oblique muscle, including the femoral arch, and also the inner column of the external inguinal ring, projecting through which is seen a portion of the spermatic cord cut; 2, the femoral arch at its insertion into the spine of the pubes. The fibres outside the numeral are those of Gimbernat's ligament; 3, the outer part of the femoral sheath; 4, the spermatic cord, after having perforated the fascia transversalis; 5, the deep femoral arch—its inner end where it is fixed to the pubes; 6, internal oblique muscle; 7, transversalis. Beneath the lower edge of this muscle is seen the transversalis fascia, which continues into the femoral sheath under the deep femoral arch; 8, conjoined tendon of the internal oblique and transversalis muscles; 9, a band of tendinous fibres directed upwards behind the external abdominal ring.

For an account of the superficial arteries and veins which ramify in the integument in the neighbourhood of the groin, see pp. 437 and 475.

* Edinb. Med. and Surg. Journal, vol. ii. p. 263, and fig. 2.

In the first edition of Hey's Practical Observations in Surgery, the upper end of this process of the fascia was named the "femoral ligament;" and since then several anatomists have distinguished the same part as "Hey's ligament." But Mr. Hey dropped the designation in the subsequent editions of the same work, and there seems no good reason for continuing it. Compare the original edition (1803), p. 151, and plate 4, with the third edition (1814), p. 147, and plates 4, 5, and 6.

The anterior or iliac part of the fascia lata being turned aside, the *sheath of the femoral vessels* will be in view. The sheath is divided by septa, so that each vessel is lodged in a separate compartment, and the vein is separated by a thin partition from the artery on one side and from the short canal for the lymphatics on the other side. Along the thigh the sheath is filled by the artery and vein, but behind the femoral arch it is widened at the inner side. Here it is perforated for lymphatic vessels, and on this account is said to be "cribriform."* This inner wider part of the sheath receives the femoral hernia; and in connection with the anatomical description of that disease it is designated the femoral canal. At its upper end the sheath of the vessels is continuous with the lining membrane of the abdomen—with the fascia transversalis at its fore part, and with the fascia iliaca behind.

When the femoral arch is being removed it will be found that a bundle of fibres springing from its under surface outside the femoral vessels, extends across the fore part of the femoral sheath, and, widening at its inner end, is fixed to the pectineal line behind Gimbernat's ligament. This fibrous band is known as the *deep femoral arch*. Connected with the same part of the bone is the conjoined tendon of the internal oblique and transverse muscles; the tendon lies before the attachment of the deep femoral arch. In many cases the last-named structure is not strongly marked; and it may be found to blend with the tendon of the muscles just referred to. Not unfrequently it is altogether wanting.

Attention may now be directed to the internal surface of the abdomen. When the peritoneum has been removed, it will be observed that the fasciæ lining the cavity form for the most part a barrier against the occurrence of hernia; for outside the iliac vessels the fascia iliaca and fascia transversalis are continuous with one another behind the femoral arch. These fasciæ are, in fact, but parts of the same membrane, to which different names are assigned for the convenience of description, just as distinctive names are applied to portions of the same artery. But where the iliac artery and vein occur, the arrangement of the fasciæ is different. The vessels rest upon the fascia iliaca; and the membranes, instead of joining at an angle as elsewhere, are continued into the sheath of the vessels in the manner above described.†

The sheath is closely applied to the artery and vein, so that in the natural or healthy state of the parts there is no space left for the formation of a hernia in the compartments which belong to those vessels; but at the inner side of the blood-vessels will be found a depression which is occupied but partly with the lymphatics. This is the femoral ring, the orifice of the femoral canal.

Femoral ring.—After the removal of the peritoneum, this opening is not at first distinctly discernible, being covered with the laminated membrane (subserous) which intervenes between the peritoneum and the walls of the abdomen. That part of the membrane which covers the ring was found by

* The word "cribriform" being applied to this part as well as to the layer of the superficial fascia stretched across the saphenous opening, the two structures are distinguished in the following manner:—the former is known as the cribriform portion of the sheath of the vessels, while to the latter is assigned the name of cribriform fascia.

† Some anatomists describe the sheath of the vessels as continued down from the membranes in the abdomen, while others regard it as an emanation from the fascia of the thigh, but continuous with the abdominal fasciæ. As this difference in the manner of viewing the structure in question does not alter the facts in any way, it is quite immaterial which of the modes of description is adopted.

Cloquet to possess in some cases considerable density; and, from being the only barrier in this situation between the abdomen and the top of the thigh, it was named by that observer the *crural septum* (septum crurale). But this structure is no more than areolar tissue with enclosed fat, and it forms oftentimes but a very slight partition. On clearing it away, the ring is displayed (fig. 346). It is a narrow opening, usually of sufficient size to admit the end of the fore finger; the size, however, varies in different cases, and it may be said to increase as the breadth of Gimbernat's ligament diminishes, and the converse. It is larger in the female than in the male body. On three sides the ring is bounded by very unyielding structures. In front are the femoral arches; behind is the hip-bone covered by the pectineus muscle and the pubic layer of the fascia lata; on the outer side lies the external iliac vein, but covered with its sheath; and on the inner side are several layers of fibrous structure connected with the pectineal line—namely, Gimbernat's ligament, the conjoined tendon of the two deeper abdominal muscles, and the fascia transversalis, with the deep femoral arch. The last-mentioned structures—those bounding the ring at the inner side—present respectively a more or less sharp margin towards the opening.

Femoral canal.—From the femoral ring, which is its orifice, the canal continues downwards behind the iliac part of the fascia lata (its falciform process), in front of the pubic portion of the same membrane, and ends at the saphenous opening. It is rather less than half an inch in length; but in its length the canal varies a little in different cases.

Blood-vessels.—Besides the femoral vein, the position of which has been already stated, the epigastric artery is closely connected with the ring, lying above its outer side. It not unfrequently happens that the obturator artery descends into the pelvis at the outer side of the same opening, or immediately behind it; and in some rare cases that vessel turns over the ring to its inner side. Moreover, an obturator vein has occasionally the same course; and small branches of the epigastric artery will be generally found ramifying on the posterior aspect of Gimbernat's ligament. In the male body, the spermatic vessels are separated from the canal only by the femoral arch.

To the foregoing account of the anatomical arrangement of the parts concerned in femoral hernia, may be added certain measurements, showing the distances of some of the most important from a given point. They are copied from the work of Sir A. Cooper:*—

	MALE.		FEMALE.	
From the symphysis pubis to the anterior spine of the ilium	5¾ inches.	..	6	inches.
From same point to the middle of the iliac vein .	2⅝	,,	... 2¾	,,
,, to the origin of the epigastric artery .	3	,,	... 3¼	,,
,, to the middle of the lunated edge of the fascia lata	3¾	,,	... 2¾	,,
,, to the middle of the femoral ring . .	2¼	,,	... 2⅝	,,

Descent of the hernia.—When a femoral hernia is being formed, the protruded part is at first vertical in its course; but at the lower end of the canal, after the passage of about half an inch, it undergoes a change of direction, bending forward at the saphenous opening; and, as it increases in size, it ascends over the iliac part of the fascia lata and the femoral arch. The hernia thus turns round those structures, passing from

* On Crural Hernia, p. 5.

behind them to their anterior surface. Within the canal the hernia is very small, being constricted by the unyielding structures which form that passage; but when it has passed beyond the saphenous opening, it enlarges in the loose fatty layers of the groin; and, as the tumour increases, it extends outwards in the groin towards the iliac spine of the hip-bone. Hence its greatest diameter is transverse.

Fig. 712.

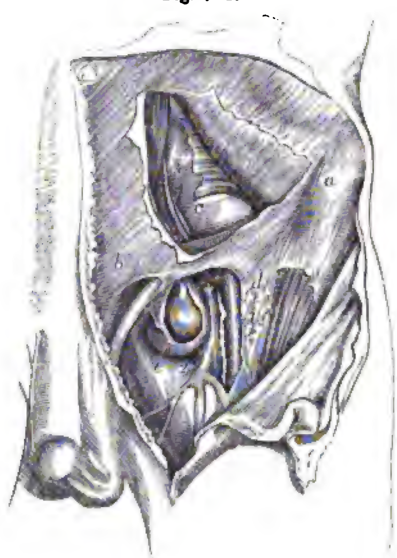


Fig. 712.—View of the relation of the Vessels of the Groin to a Femoral Hernia, &c. (from R. Quain). ½

In the upper part of the figure a portion of the flat muscles of the abdomen has been removed, displaying in part the transversalis fascia and peritoneal lining of the abdomen; in the lower the fascia lata of the thigh is in part removed and the sheath of the femoral vessels opened: the sac of the femoral hernial tumour has also been opened.

a, anterior superior spinous process of the ilium; *b*, aponeurosis of the external oblique muscle above the external inguinal aperture; *c*, the abdominal peritoneum and fascia transversalis; *d*, the iliac portion of the fascia lata near the saphenic opening; *e*, sac of a femoral hernia; 1, points to the femoral artery; 2, femoral vein at the place where it is joined by the saphenic vein; 3, epigastric artery and vein passing up towards the back of the rectus muscle; +, placed upon the upper part of the femoral vein close below the common trunk of the epigastric and an aberrant obturator artery; the latter artery is seen in this case to pass close to the vein and between it and the neck of the hernial tumour.

Coverings of the hernia.—The sac which is pushed before the protruded viscus, is derived from the external fossa of the peritoneum; except, however, when the cord of the obliterated umbilical artery is placed outside its ordinary position, in which case the serous membrane furnishes the sac from its internal fossa. After the sac, the hernia carries before it the subserous membrane (septum crurale of Cloquet), which covers the femoral ring, and likewise an elongation from the sheath of the femoral vessels. These two structures combined constitute a single very thin covering, known as the fascia propria of the hernia (Cooper). It sometimes happens that the hernia is protruded through an opening in the sheath, which therefore in that event does not contribute to form the fascia propria.

Diagnosis.—Passing over the general symptoms of abdominal herniæ and the means of forming the diagnosis between a hernia and several other diseases with which it is liable to be confounded,—subjects which fall within the province of treatises on practical surgery,—the observations to be made in this place may be limited to the anatomical circumstances which characterise femoral hernia, and serve to distinguish it from the inguinal form of the complaint. When the inguinal hernia descends to the scrotum or to the labium pudendi, and when the femoral hernia extends some distance

outwards in the groin, no error in diagnosis is likely to arise. It is only in distinguishing between a bubonocele and a femoral hernia of moderate size that a difficulty occurs. The position of the femoral hernia is, in most cases, characteristic. The tumour is upon the thigh, and a narrowed part, or neck, may be felt sinking into the thigh near its middle. Besides, the femoral arch is usually to be traced above this hernia, while that band is lower than the mass of a tumour lodged in the inguinal canal. At the same time the inguinal tumour covers the femoral arch, and cannot be withdrawn from it like a femoral hernia, when it has turned over that cord. Some assistance will be gained, in a doubtful case, from the greater facility with which the tumour emerging at the saphenous opening admits of being circumscribed, in comparison with the bubonocele, which is bound down by a more resistent structure—the aponeurosis of the external oblique muscle. Other practical applications of the foregoing anatomical observations come now to be considered.

The taxis.—During the efforts of the surgeon to replace the hernia, the thigh is to be flexed upon the abdomen and inclined inwards, with a view to relax the femoral arch; the tumour is, if necessary, to be withdrawn from over the arch, and the pressure on it is to be directed backwards into the thigh.

The operation.—The replacement of the hernia by the means just adverted to being found impracticable, an operation is undertaken with the view of dividing the femoral canal (or some part of it), thereby widening the space through which the protruding viscus is to be restored to the abdomen, or with the view of relieving strangulation when the restoration of the part is not possible or not desirable. Inasmuch as the manner of conducting the operation chiefly depends on the place at which the constricting structures are to be cut into, it will be convenient in the first instance to determine this point; and with this object we shall inquire into the practicability and safety of making incisions into the femoral canal at different points of its circumference. As the hernia rests upon the pelvis, the posterior part of the canal may at once be excluded from consideration; so likewise may its outer side on account of the position of the femoral vein, and also the outer part of its anterior boundary, because of the presence of the epigastric artery in this direction. There remains only the inner boundary with the contiguous part of the anterior one, and through any point of this portion of the ring or canal an incision of the required extent (always a very short one) can be made without danger in nearly all cases. The sources of danger are only occasional; for the urinary bladder, when largely distended, and the obturator artery when it turns over the femoral ring—a very unusual course—are the only parts at the inner side of the hernia liable to be injured; while the last-named vessel, when it follows the course just referred to, and in the male the spermatic cord, are the structures in peril when the anterior boundary of the canal is cut into towards the inner side of the hernia (see p. 624 and fig. 291).

Returning now to the steps of the operation:—After it has been ascertained that the urinary bladder is not distended, the skin is to be divided by a single vertical incision made on the inner part of the tumour, and extending over the crural arch. When the subcutaneous fat (the thickness of which is very various in different persons) is cut through, a small blood-vessel or two are divided, and some lymphatic glands may be met with. The hæmorrhage from the blood-vessels seldom requires any means to restrain it; but the glands, if enlarged, retard the operation in some

degree. The fascia propria of the hernia, which succeeds to the subcutaneous fat, is distinguished by its membranous appearance and the absence of fat. It is very thin, and caution is required in cutting through it, as the peritoneal sac is immediately beneath : the two membranes are indeed in contact, except in certain cases to be presently noticed. A flat director is now to be insinuated between the hernial sac and the inner side of the femoral canal, space for the instrument being gained by pressing its smooth surface against the neck of the hernia. On the groove of the director so introduced, or under the guidance of the fore finger of the left hand if the use of the director should be dispensed with, the probe-pointed bistoury is passed through the canal, and the dense fibrous structure of which it consists is divided, the edge of the knife being turned upwards and inwards, or directly upwards. By the former plan of relieving the stricture, the parts divided are the following, —viz., the falciform process of the fascia lata and the structures fixed to the pectineal line of the pubes, namely, Gimbernat's ligament, and, it may be, the tendon of the two deep abdominal muscles, with the fascia transversalis, and the inner end of the deep femoral arch ; while if the incision be directed upwards, the falciform process of the fascia lata and the two femoral arches are divided. The opening being sufficiently dilated, the protruded part is restored to the abdomen as with the taxis.

But it may be found necessary to lay open the hernial sac in order to examine its contents, or in order to relieve the impediment to the return of the hernia if that should happen to reside in the neck of the sac itself. In this case it will probably be required to add to the vertical incision already made through the integuments and superficial fascia, another directed outwards over the tumour, and parallel with the femoral arch. Such additional incision is readily made, by passing the scalpel beneath the integument and fat, and cutting outwards after the skin has been pierced with the point of the knife. The sac being now opened, the hernia knife is used at the inner side of its neck, while the bowel is guarded with the left hand. During the restoration of the protruded parts, some advantage will be gained if the edges of the divided sac should be held down with a pair or two of forceps in the hands of an assistant.

In the foregoing observations, it has been stated that the fascia propria is in contact with the sac of the hernia, except in certain cases. The exception is afforded by the interposition of fat, and sometimes in considerable quantity. The adipose substance is deposited in the subserous membrane ; it has the peculiarity of resembling the fat lodged in the omentum, and it is occasionally studded with small cysts, containing a serous fluid. The hernia will be most readily found in such circumstances behind the inner part of the adventitious substance ; which should be turned outwards from the inner side, or cut through.

III.—THE PERINÆUM AND ISCHIO-RECTAL REGION.

A connected view of the structures which occupy the outlet of the pelvis becomes necessary, in consequence of the important surgical operations occasionally performed on the genito-urinary organs and the rectum, which are contained in that part. In the examination of these structures, which it is proposed to make in this place, attention will be confined to the male body.

The hip-bones as they bound the outlet of the pelvis are already

sufficiently described (p. 97). The anterior portion of the space, which is appropriated to the urethra and the penis, is named the *perinæum*. This part is triangular, the sides being formed by the sides of the pubic arch meeting at the symphysis pubis, while a line extended between the two ischial tuberosities represents the base of the triangle. In well-formed bodies the three sides of the space are equal in length; but cases occur in which, by the approximation of the ischiatic tuberosities, the base is narrowed; and we may anticipate the practical application of the anatomical facts so far as to state here, that this circumstance exercises a material influence on the operation of lithotomy, inasmuch as the incisions required in that operation, instead of being oblique in their direction, must, in such circumstances, be made more nearly straight backwards.

That portion of the outlet of the pelvis which lies behind the perinæum may be named the ischio-rectal region. It contains the end of the rectum; and it is defined by the ischial tuberosities, the coccyx, and the great gluteal muscles. We shall now proceed to the detailed examination of the two parts thus mapped out.

The skin of the *perinæum* continued from the scrotum, and partaking of the characters it has on that part, is dark-coloured, thin, and extensible, loosely connected with the subjacent textures, and in the male body studded with crisp hairs. Around the anus, it is thrown into folds, which are necessary to allow the extension of the orifice of the bowel, during the passage of masses of fæcal matter; and along the middle of the perinæum the median ridge or raphe of the scrotum is continued backwards to the anus. By this mark upon the skin, the large triangle in which is comprised

Fig. 713.

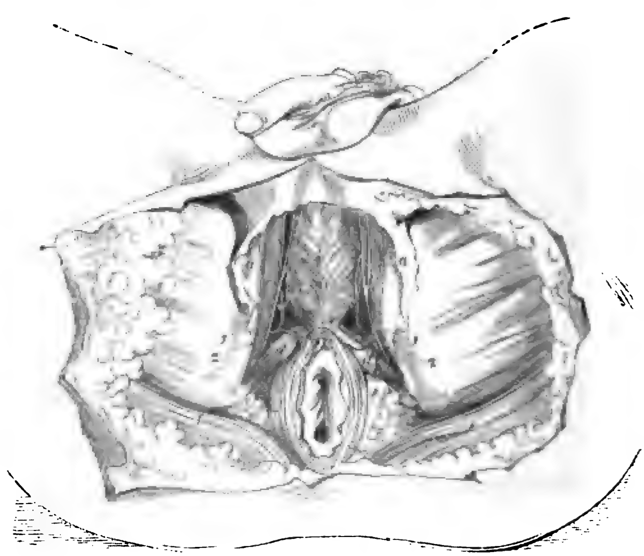


Fig. 713.—Superficial Dissection of the Perinæum and part of the Thighs.

a, superficial fascia; *b*, accelerator urinæ; *c*, erector penis; *d*, transversus perinæi; *e*, upper point of sphincter ani; *f*, the edge of the gluteus maximus; 1, superficial perineal artery; 2, superficial perineal nerve.

the whole perinæum, is subdivided into two equal parts. To one of these smaller spaces the operations usually performed for gaining access to the urinary bladder are for the most part restricted. The skin of the perinæum is provided with numerous sebaceous follicles.

From the muscles of the perinæum the skin is separated by areolar tissue and fat, except in the neighbourhood of the anus, where the sphincter of the bowel is immediately in contact with the integument. The deeper part of the fatty subcutaneous membrane,—the *superficial fascia* (p. 259),—taking on a fibrous appearance, has, in a great measure, the same arrangement and characters as the corresponding structure of the groin. With that membrane the layer is continuous in front through the scrotum, but at other points it is confined to the perinæum, being fixed laterally to the sides of the pubic arch, while it is continued posteriorly, beneath the sphincter ani and in front of the rectum, into the deep perineal fascia. It is in consequence of these connections of the superficial fascia, that abscesses do not attain a large size in the perinæum, and that urine effused in consequence of rupture of the urethra does not extend backwards to the rectum or outwards to the thigh, but continues forwards, and, if an outlet for its escape should not be afforded by the surgeon, reaches successively the scrotum, the penis, and the groin above Poupart's ligament. In extreme cases the extravasated fluid would spread from the position last mentioned over the anterior part of the abdomen and even to the thorax, its extension downwards to the thigh being restrained by the attachment of the superficial fascia along the fold of the groin.

Fig. 714.

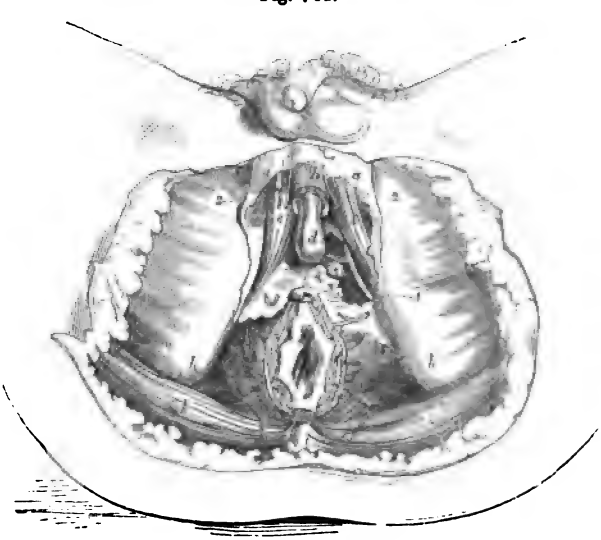


Fig. 714.—Deeper Dissection of the Perinæum.

The perineal muscles have been removed and also the fat in the ischio-rectal fossa; *a*, superficial fascia; *b*, accelerator urinæ; *c*, crus penis; *d*, the bulb; *e*, triangular ligament of the urethra; *f*, levator ani; *g*, sphincter; *h*, tuberosity of the ischium; *k*, gluteus maximus; *, Cowper's gland of the left side; 1, pudic artery; 2, superficial perineal artery and nerve. The inferior hæmorrhoidal arteries and the artery of the bulb are likewise shown.

The *muscles* brought into view by the removal of the superficial fascia are, on each side, the accelerator urinæ, erector penis, and transversus perinæi. Between these muscles is a depression, in which access may be gained to the membranous part of the urethra, without wounding the erectile tissues of the penis,—viz., the corpus spongiosum urethræ with its bulbous enlargement on the one hand, and the crus of the corpus cavernosum on the other, covered respectively by the accelerator urinæ and the erector penis. Along this depression is placed the superficial artery of the perinæum, with the accompanying nerve, and the transverse artery crosses behind it; at the bottom of the depression, after the muscular structure has been turned aside, the deep perineal fascia is met with.

The last-named membrane, *deep perineal* or *subpubic fascia* (p. 260), fills the upper part of the subpubic arch, and is therefore necessarily triangular in shape. It consists of two laminæ of fibrous membrane, the anterior being much the more fibrous of the two. The layers are separated by an interval, in which the constrictor muscle of the urethra (p. 265) is lodged, together with Cowper's glands and the arteries of the bulb, as well as the pudic arteries and nerves for a short space. Where it is perforated by the membranous portion of the urethra, the fore part of the deep perineal fascia is continuous with the fibrous cover of the bulb and corpus spongiosum urethræ, so that the fascia does not present a defined edge to the tube which passes through it. The posterior layer is connected with the capsule of the prostate gland.

The anterior of the two layers constituting the deep perineal fascia is the structure recognised by most anatomical writers as forming the *triangular ligament of the urethra*. (See especially Camper, Demonstrationes Anatomico-Pathologicæ.) It is pierced by the urethra, and it alone interferes with the passage of instruments along the canal.

The structure next met with in examining the perinæum is the levator ani (its fore part), and immediately under that muscle is the prostate. Of this gland it is here necessary only to state, as material to the present object, that placed before the neck of the bladder (when the perinæum is in the position required for the performance of lithotomy), around the urethra, behind and below the arch of the pubes, and above the rectum, the prostate is supported by the levator ani and the pelvic fascia,—the latter descending from the pubes on its upper surface. It is invested with a fibrous covering, and on this account the outer surface does not readily yield to a cutting instrument, while the proper substance of the gland may be incised with comparative facility. From the increase of its breadth towards the lower surface, it follows that the greatest extent of incision from the urethra, without wholly dividing the gland, would be made in a direction outwards and backwards.

The examination of the prostate by the surgeon is made through the rectum. It is only through the gut that it can be felt. When the gland is enlarged, as it commonly is in aged persons, the urethra is raised above its natural level and elongated. But the augmentation of size may be partial, affecting one lateral lobe (a rare occurrence), and then the urethra is inclined to one side; or the middle and posterior part or middle lobe may be projected upwards at the orifice of the urethra, so as even to obstruct the escape of urine from the bladder. In this last case the point of the instrument passed along the urethra, must be inclined upwards more than is required in the healthy condition of the parts, in order that it may

be made to enter the bladder over the projection referred to. The part of the urethra encircled by the prostate admits of considerable dilatation. For the position of the seminal and other openings into it, reference may be made to the description of the canal at page 961.

Behind the prostate the neck of the urinary bladder presents itself. Here the bladder is bound to the pubes at its upper part by the pelvic fascia, the bands of which are named its anterior ligaments. Laterally the fascia

Fig. 715.

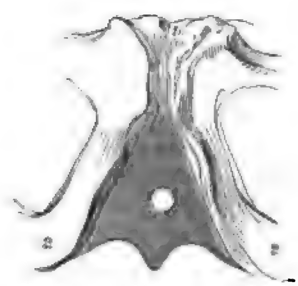


Fig. 715.—The Bones of the Subpubic Arch with the Anterior Part of the Deep Perineal Fascia.

In consequence of the connection between the fascia and the fibrous covering of the bulb having been cut, the passage for the urethra appears as a hole. 1, pubes near the symphysis, 2, hip-bone close to its tuberosity; 3, deep perineal fascia—its anterior surface.

reaches the organ in question over the side of the prostate; and an elongation from the same membrane extends from side to side between the bladder and the rectum, after investing the vesiculæ seminales and vasa deferentia.

Turning attention in the next place to the *rectum*, which occupies the irregularly-shaped space behind the perinæum, we shall recall a few particulars respecting it. The lowest or third division of the bowel, which measures about an inch and a half in length, is directed obliquely back-

Fig. 716.

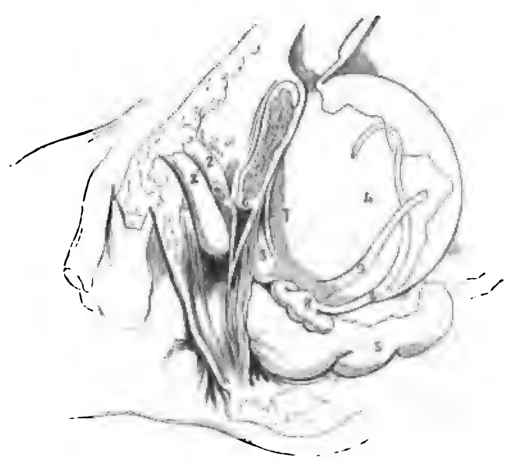


Fig. 716.—The Pelvic Viscera of the Male seen on the Left side.

1, the body of the pubes sawn through; 2, corpus cavernosum penis; 2′, corpus spongiosum; 3, prostate gland with a portion of the levator ani covering its fore part; 4, urinary bladder; 5, intestinum rectum; 6, deep perineal fascia—its two layers; 7, cut edge of the pelvic fascia extending from the pubes to the back part of the prostate; 8, vas deferens; 8′, vesicula seminalis; 9, ureter. The jagged cut edge of the peritoneum is seen passing over the bladder and rectum.

wards from the fore part of the prostate to the anus; and as at the same time the urethra here inclines forwards with the penis, the space between the two widens towards the surface of the perinæum. Into this space the bulb of the corpus spongiosum drops down, occupying it more or less

according as the erectile tissue is more or less distended. The part of the rectum now under consideration narrows to its end under the influence of the sphincters. It is supported by the levatores ani, which are fixed to its sides, and by the pelvic fascia on the inner surface of those muscles.

From this, its shortest and narrowest part, the intestine sweeps into the hollow of the sacrum, widening considerably at the same time so as to form a large pouch. This part, which is known as the second division of the rectum, has before it the prostate and the urinary bladder with the seminal vesicles, and above these the recto-vesical pouch of the peritoneum. The

Fig. 717.

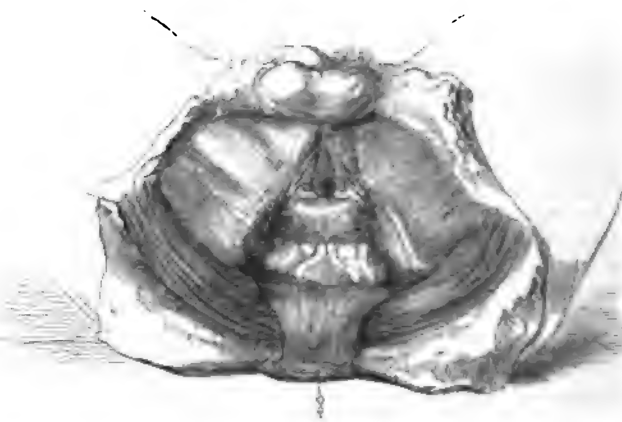


Fig. 717.—The Prostate Gland and Base of the Bladder exposed in the Perinæum.

Besides the superficial fascia and the perineal muscles, by the removal of which the spongy erectile tissue and the crura penis were uncovered, the anterior layer of the deep perineal fascia was cut away in the preparation for this sketch, and thus the pudic arteries with their branches for the bulb, and Cowper's glands, have been laid bare. The rectum, too, having been dissected from its connections and drawn back, the prostate gland, the seminal vesicles, and part of the urinary bladder have been brought into view. 1, fascia lata covering the adductor muscles of the thigh; 2, gluteus maximus; 3, rectum; 4, crus penis of left side; 5, corpus spongiosum urethræ; 6, prostate; 7, vesicula seminalis and vas deferens of left side; 8, a small part of the urinary bladder; 9, right dorsal artery, with the artery of the bulb and Cowper's gland resting against the inner layer of the deep perineal fascia. The last-named parts are at considerable depth, but the size within which it was necessary to restrict the drawing, did not admit of the appearance of depth being sufficiently represented.

rectum and the bladder are in contact with each other only in the small triangular space intercepted between the seminal vessels and the peritoneum; and in this space the bladder may be punctured, in order to evacuate its contents. In performing the operation, the chief guide to the surgeon is the prostate. The instrument is to be passed forwards into the bladder behind this gland; but care must be taken to regulate the distance from its margin, so as to avoid wounding on the one hand the vasa deferentia which come into apposition one with another immediately behind it; and, on the other hand, the peritoneum where this membrane turns from one of the organs to the other. At the same time it is to be remembered, that by the inclination of the trocar to either side the seminal vesicles would be

endangered. The part of the intestine now under observation rests against the conjoined levatores ani, the coccyx, and the sacrum.

The lower end of the rectum receives small arteries on each side from the pudic; but its principal artery (the superior hæmorrhoidal, the continuation of the inferior mesenteric, p. 412,) descends behind the organ and ends in branches about three inches from the anus, which enter the gut and anastomose in loops opposite the internal sphincter. The veins, like those of the abdomen generally, are without valves. These vessels are very liable to enlarge and become varicose; and this condition is constantly associated with or even forms a great part of the disease known as hæmorrhoids.

Ischio-rectal fossa.—On each side of the rectum between it and the ischial tuberosity is contained a considerable quantity of fat, the space which it occupies being named the ischio-rectal fossa. This hollow extends backwards from the perinæum to the great gluteal muscle; it is bounded on the inner side by the levator ani as this muscle descends to support the intestine, and on the opposite side by the obturator fascia and muscle supported by the hip-bone. At the outer side and encased in a sheath of the obturator fascia is the pudic artery with the accompanying veins and nerve; and small offsets from these cross the fossa to supply the lower end of the rectum. The pudic artery, it will be observed, is about an inch above the lower surface of the tuber ischii, and at the same time, by its position under that prominence of the bone, it is protected from injury by incisions directed backwards from the perinæum; but in front of this part (in the perinæum proper), inasmuch as the vessel lies along the inner margin of the subpubic arch, it is here liable to be wounded when the deeper structures of the perinæum are incised.

The fossa is narrowed as it reaches upwards into the pelvis; such narrowing of the space is the necessary result of the direction of the levator ani, which drops inwards from the fascia on the side of the pelvis, and thus limits the fossa at its upper end.

LATERAL OPERATION OF LITHOTOMY.

The intention of the operation, as it is usually performed, is to remove a calculus from the urinary bladder by an opening made through the perinæum and the prostatic part of the urethra. The incisions to attain this end are commonly made on the left half of the perinæum: because this side is most convenient to the right hand of the operator; but if the surgeon should operate with the left hand, then the opposite (right) side of the perinæum would be most convenient.

The position at which the perinæum is to be incised requires careful consideration. For if the necessary incisions should be made too near the middle line of the body, the bulbous enlargement of the corpus spongiosum urethræ and the rectum are liable to be wounded; and if, on the other hand, the perinæum should be divided towards its outer boundary (the pubic arch), there is a risk of wounding the pudic artery where that vessel has reached the inner edge of the bone. The incisions are therefore to be made through the area of the small perinæal space in such manner as to avoid both its sides. Again, as to the length to which the several structures are to be incised:—The integument and the subcutaneous fatty layer must be divided with freedom, because, first, the skin does not admit of dilatation during the removal of the foreign body; and, secondly, extensive incisions through the structures near the surface facilitate the egress

of urine, which, after the operation, continues for a time to trickle from the bladder. But the prostate and the neck of the bladder, on the contrary, are to be incised only for a small extent. The reasons for this rule may be stated as follows :—By accumulated experience in operations on the living body, it has been found that the structures now under consideration, when slightly cut into, admit of dilatation, so as to allow the passage of a stone of considerable size, and that no unfavourable consequence follows from the dilatation. Moreover, when these parts are freely divided (cut through), the results of lithotomy are less favourable than in the opposite circumstances. The less favourable results adverted to appear to be due to the greater tendency to infiltration of urine in the subserous tissue of the pelvis ; and the occurrence of this calamity probably depends on the fact that when the prostate has been fully cut through, the bladder is at the same time divided beyond the base of the gland, and the urine then is liable to escape behind the pelvic fascia (which it will be remembered is connected with both those organs at their place of junction) ; whereas if the base of the gland should be left entire, the bladder beyond it is likewise uninjured, and the urine passes forwards through the external wound.

The steps of the operation by which the foregoing general rules are sought to be carried out are the following :—The grooved staff having been passed into the bladder (and this instrument ought to be of as large size as the urethra will admit), and the body or the patient, as the case may be, having been placed in the usual position—by which position the perinæum is brought fully before the operator with the skin stretched out—the first incision is begun about two inches before the anus, a little to the left of the raphe of the skin, and from this point it is carried obliquely backwards in a line about midway between the tuber ischii and the anus, extending a little way behind the level of the latter. During the incision, the knife is held with its point to the surface, and it is made to pass through some of the subcutaneous fatty layer as well as the skin. Now, the edge of the knife is applied to the bottom of the wound already formed, in order to extend it somewhat more deeply ; and the fore-finger of the left hand is passed firmly along for the purpose of separating the parts still farther, and pressing the rectum inwards and backwards out of the way. Next, with the same finger passed deeply into the wound from its middle and directed upwards, the position of the staff is ascertained, and the structures still covering that instrument are divided with slight touches of the knife,—the finger pressing the while against the point at which the rectum is presumed to be. When the knife has been inserted into the groove of the staff (and it reaches that instrument in the membranous part of the urethra) it is pushed onwards through the prostatic portion of the canal with the edge turned to the side of the prostate, outwards, or, better, outwards with an inclination backwards. The knife being now withdrawn, the forefinger of the left hand is passed along the staff into the bladder. With the finger the parts are dilated, and with it, after the staff has been withdrawn, the position of the stone is determined and the forceps is guided into the bladder.

In case the calculus is known to be of more than a moderate size, and the knife used is narrow, the opening through the side of the prostate may be enlarged as the knife is withdrawn, or the same end may be attained by increasing the angle which that instrument, while it is being passed onwards, makes with the outer part of the staff. And if the stone should be of large size, it will be best to notch likewise the opposite side of the prostate before

the forceps is introduced. The same measure may be resorted to afterwards should much resistance be experienced when the foreign body is being extracted. Lastly, this part of the operation (the extraction of the stone)

Fig. 718.

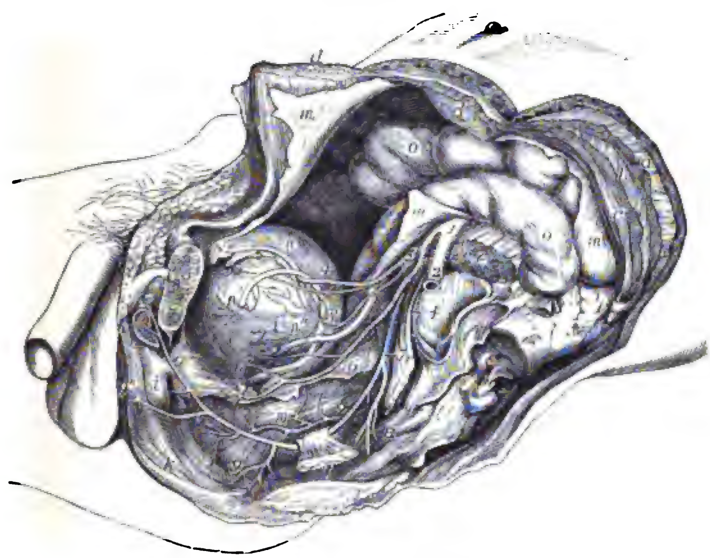


Fig. 718.—VIEW OF THE DISTRIBUTION OF THE ARTERIES TO THE VISCERA OF THE MALE PELVIS, AS SEEN ON THE REMOVAL OF THE LEFT OS INNOMINATUM, &c. (from R. Quain). ½

a, left external oblique muscle of the abdomen divided; *b*, internal oblique; *c*, transversalis; *d*, *d*, the parts of the rectus muscle divided and separated; *e*, psoas magnus muscle divided; *f*, placed on the left auricular surface of the sacrum, points by a line to the sacral plexus of nerves; *g*, placed on the os pubis, sawn through a little to the left of the symphysis, points to the divided spermatic cord; *h*, the cut root of the crus penis; *i*, the bulb of the urethra; *k*, elliptical sphincter ani muscle; *l*, a portion of the ischium near the spinous process, to which is attached the short sacro-sciatic ligament; *m*, the parietal peritoneum: *n*, the upper part of the urinary bladder; *n*, *n'*, the left vas deferens descending towards the vesicula seminalis; *n''*, the left ureter; *o*, the intestines; 1, the common iliac at the place of its division into external and internal iliac arteries; 2, left external iliac artery; 3, internal iliac; 4, obliterated hypogastric artery, over which the vas deferens is seen passing, with the superior vesical artery below it; 5, middle vesical artery; 6, inferior vesical artery, giving branches to the bladder, and descending on the prostate gland and to the back of the pubes; 7, placed on the sacral plexus, points to the common trunk of the pudic and sciatic arteries; close above 7, the gluteal artery is seen cut short; 8, sciatic artery cut short as it is escaping from the pelvis; 9, placed on the rectum, points to the pudic artery as it is about to pass behind the spine of the ischium; 9', on the lower part of the rectum, points to the inferior hæmorrhoidal branches; 9'', on the perinæum, indicates the superficial perineal branches; 9''', placed on the prostate gland, marks the pudic artery as it gives off the arteries of the bulb and of the crus penis; 10, placed on the middle part of the rectum, indicates the superior hæmorrhoidal arteries as they descend upon that viscus.

should be conducted slowly, so as gradually to dilate the parts without lacerating them; and the forceps should be held with its blades one above the other.

The Structures divided in the Operation.—In the first incision the integument and the subjacent fatty layer are divided; afterwards a small part

of the accelerator urinæ, and the transversus perinæi with the transverse artery. Then the deep perineal fascia with the muscular fibres between its layers, the membranous part of the urethra, the prostatic part of the canal, and, to a small extent, the prostate itself are successively incised.

The Blood-vessels: their relation to the incisions.—The transverse artery of the perinæum with, it may be, the superficial artery of the perinæum, is the only artery necessarily cut through when the vessels have their accustomed arrangement; for in such circumstances the artery of the bulb is not endangered if the knife be passed into the staff in a direction obliquely upwards, the artery being anterior to the groove of that instrument; neither is there a risk of wounding the pudic artery, unless the incisions through the deep parts (the prostate for instance) should be carried too far outwards.*

But in some cases the arteries undergo certain deviations from their accustomed arrangement, whereby they are rendered liable to be wounded in the operation. Thus, the artery of the bulb when it arises, as occasionally happens, from the pudic near the tuber ischii, crosses the line of incision made in the operation.† The arterial branches ramifying on the prostate are in some instances enlarged, and become a source of hæmorrhage,‡ and the veins, too, on the surface of that gland, when augmented in size, may give rise to troublesome bleeding.§ Lastly, it should be added that the occasional artery (accessory pudic), which takes the place of the pudic when defective, inasmuch as it lies on the posterior edge of the prostate, might be divided if the gland were cut through to its base, and only in this event.||

* For reference to some cases in which the pudic artery was divided in lithotomy, see Crosse's "Treatise on Urinary Calculus," p. 21. London, 1835.

† "The Anatomy of the Arteries," &c., by R. Quain, p. 442, and plate 64†, figs. 1 and 2. A case in which death resulted from division of the artery of the bulb is recorded by Dr. Kerr, in the "Edinb. Med. and Surg. Journal," July, 1847, p. 155.

‡ See an essay, entitled "Remarks on the Sources of Hæmorrhage after Lithotomy," by James Spence, in the "Edinburgh Monthly Journal of Medical Science," vol. i. p. 166; 1841. And "The Arteries," &c., by R. Quain, p. 445.

§ "The Arteries," &c., by R. Quain, p. 446, and plate 65, fig 3.

|| Ibid. p. 444, and plate 63. An instance in which fatal consequences resulted from the division of such an artery has been placed on record. See "Case of Lithotomy attended with Hæmorrhage," by J. Shaw, in "The London Medical and Physical Journal," vol. lv. p. 3, with a figure. 1826.

DIVISION III.

DISSECTIONS.

THE object of the following Directions is to serve as a short and simple guide for the display of the structure of the body by students in dissecting-rooms, the various organs and their parts being mentioned in the order in which they may best be exposed, and such methods being indicated as may enable each student to obtain the greatest amount of information from his dissection, and at the same time to prevent interference among the neighbouring dissectors as much as possible.

I. GENERAL MANAGEMENT OF THE DISSECTIONS.

1. In different schools various plans are pursued in the allotment of portions of the body to different dissectors. According to the method here recommended, the subject is divided into ten parts, five on each side of the body, which are left in connection with one another until the dissection is sufficiently advanced to admit of their being conveniently separated. The boundaries of the parts are so adjusted, that by their due observance interference between the different dissectors may be as much as possible avoided.

2. In the case of a male subject, a day is recommended to be set apart at the commencement for the dissection of the perinæum. Thereafter, and in the case of a female subject, immediately on its being brought into the rooms, the subject is to be placed with the face downwards for four days, during which time the posterior regions are to be dissected, in so far as within reach, in the order afterwards mentioned for each part. It is then to be turned and laid upon its back, when a dissection of the various parts in front is to be made. The whole dissection is supposed to be completed within six weeks,—the time fixed by the Anatomy Act.

3. The dissection of the head and neck and of the limbs should be begun at once when the subject is laid upon its face; that of the abdomen as soon as it is turned on the back, and the thorax must not be opened until the upper limbs are removed. The limbs ought not to be removed until the parts which connect them with the trunk have been fully dissected, and an opportunity has been given for the examination of the surgical anatomy of the subclavian artery and the parts concerned in hernia, by the dissectors of the head and the abdomen; all of which may be accomplished before the tenth day. The further dissection of the several parts may then proceed in accordance with the methods suggested in the special directions.

4. It is to be observed that, although in the special directions all the organs mentioned are supposed to be brought under review in one dissection, it may be necessary for the student, in order to obtain a full knowledge of them, to dissect each of the parts more than once. This is especially the case with the head and neck. It is incumbent therefore upon the student to make a selection of different objects in each dissection, under the guidance of the demonstrator, in order that he may progressively obtain a full view of the whole.

5. Those students who have not previously dissected, are recommended to select the limbs for their first and second dissections, after they shall have obtained a sufficient knowledge of the bones and joints; and for the most part, the junior students ought not, in a first or second dissection, to attempt to expose more than the muscles and the largest vessels and nerves. In their third and subsequent dissections they will gradually come to make a more complete display of all the parts.

6. In the dissection of the limbs, no interference between the dissectors of opposite sides can occur; but in the head and neck, thorax and abdomen, there is a necessity for the students who are engaged with the parts of opposite sides to act in concert. The viscera must be examined by them together, and it will frequently happen that the dissectors of only one side can work at the same time. When such is the case, the one dissector should give his assistance to the other by reading or otherwise; and it will sometimes be found advantageous for those having the same parts of opposite sides to make in concert different kinds of dissections on the opposite sides of the body; as for example, to dissect the muscles chiefly on one side, and the vessels and nerves on the other, or the orbit from above on one side, and in a lateral view on the other, etc.

II. SPECIAL DIRECTIONS FOR THE DISSECTION OF EACH PART.

I.—Head and Neck.

The right and left sides of this region constitute each a part. Its dissection may occupy the full time, or about six weeks; two hours or more daily being devoted to it. Its inferior boundary extends from the sternum, along the clavicle, to the acromion process; and thence to the spinous process of the third cervical vertebra. It may be found impossible to follow out in one part the whole of the dissections indicated below; and therefore the dissector ought rather, if his time is limited, to make a selection for repeated dissections, following, as nearly as possible, the methods described. Many of the smaller points of detail may be passed over by the junior student; and there are some which can only be observed in a favourable condition of the subject.

1. *Integument of the Cranium.*—The subject being placed with the face downwards, during the first two days, the scalp and the back of the neck (to the third cervical vertebra) are to be dissected; and while this is being done, only one dissector should work at a time. An incision is to be made along the middle line, from the spinous process of the third cervical vertebra, forwards over the head, to the root of the nose, and another from immediately behind the ear to meet the first at the vertex, care being taken not to cut deeper than through the skin. The flaps of integument thus marked out are to be reflected from above downwards, the posterior one first.

At the back of the neck the posterior and upper parts of the trapezius and sterno-mastoid muscles will be laid bare (pp. 200 and 193); and, between these, a part of the splenius muscle, and, when the trapezius is not strongly developed, a small angle of the complexus muscle will be brought into view. These muscles are to be left undivided at present. On the posterior part of the cranium the structures to be examined are the occipital artery and vein, and the great occipital nerve, which pierces the complexus and trapezius muscles (pp. 351 and 634); the small occipital nerve, which passes upwards along the posterior border of the sterno-mastoid muscle (p. 638); and, beneath these, the occipital part of the occipito-frontalis muscle (p. 169), which passes upwards from the superior curved line of the occipital bone. Behind the ear are the retrahens auriculam muscle and the posterior auricular artery and nerve (pp. 353 and 612); above the ear is the attollens auriculam muscle; and in front of the ear the attrahens auriculam muscle connected with the attolens, the temporal artery and vein, the small temporal branch of the third division of the fifth nerve, and the superior branches of the facial nerve (pp. 170, 353, 612, and 606). Passing upwards on the forehead, are the frontal part of the occipito-frontalis muscle, the frontal vein, the supraorbital and frontal arteries, and the supraorbital and supratrochlear nerves (pp. 360 and 597).

2. *Interior of the Cranium and Brain.*—During the third and fourth days the brain and its membranes are to be removed and studied, and the interior of the base of the skull dissected to show the sinuses, blood-vessels, and nerves; and, if there is time (as may be the case, should the head have been previously opened), the orbit may be examined from above. To remove the calvarium, the temporal aponeurosis and upper part of the temporal muscle having been dissected, let the scalpel be carried round the cranium from a point a little above the occipital protuberance, so as to pass across the forehead at about an inch above the orbits; and having cleared a small portion of the bone on the circle so made, let the external table of the skull be sawn through, leaving the inner table undivided. Let the inner table be cracked completely round by a few smart strokes of the chisel and mallet, and the calvarium may then be pulled away from the dura mater which lines it. The superficial aspect of the dura mater having been observed, and the superior longitudinal sinus laid open and inspected (p. 462), the dura mater is to be divided on a level with the sawn edge of the skull, excepting where it touches the middle line; this will permit the arachnoid membrane and pia mater to be examined, as well as the cerebral veins entering the superior longitudinal sinus; and when these veins are divided the falx cerebri will be seen dipping down between the cerebral hemispheres. The falx cerebri is then to be separated from its attachment to the crista galli and thrown backwards (p. 562).

It will now be in the dissector's option to remove the brain at once from the body, or to examine it in situ as far as the ventricles. If the latter plan, which is generally to be preferred, be adopted, the dissectors ought first to examine the convolutions of the upper aspect of the brain, noticing the anterior and posterior cerebral arteries arching respectively backwards and forwards; they will then slice away the hemispheres to the level of the corpus callosum, and observe the extent of that structure, its transverse markings, the raphe and the longitudinal lines (p. 540). They will proceed by incisions at the sides of the corpus callosum, to open the lateral ventricles separately, so as to expose their cavities with the anterior and posterior cornua and the parts lying on their floor: they must afterwards cut across

the corpus callosum near the forepart, and raising it carefully, divide with scissors the septum lucidum which separates the lateral ventricles, and notice between its layers the fifth ventricle. The lateral ventricles having been thus thrown into one, the structures forming their floor are more fully seen, viz., the corpora striata, tæniæ semicirculares, the optic thalami in part, the choroid plexus, the upper surface of the fornix, the foramen of Monro, the anterior and posterior cornua, and the hippocampus minor. The descending cornu is now to be exposed, on one side only, by cutting away the cerebral substance above and external to it, and in it will be found the hippocampus major, pes hippocampi, tænia hippocampi, and fascia dentata.

The fornix is to be divided immediately above the foramen of Monro, and reflected; by which means its inferior surface will be brought into view, as also the upper surface of the velum interpositum. The connections of the anterior extremity of the velum may then be cut across, and that structure likewise turned back so as to lay bare the third ventricle; but in doing this care should be taken lest the pineal body, which is adherent to the under surface of the velum interpositum near its back part, should be raised out of its place. The objects seen in and near the third ventricle, are now to be studied: viz., the optic thalami, the three smaller commissures, viz., anterior, middle and posterior, the pineal body and its crura, the corpora quadrigemina, and the anterior opening of the iter a tertio ad quartum ventriculum; also the anterior crura of the fornix should be traced down as far as possible towards the corpora albicantia. The velum having been replaced, the transverse fissure of the cerebrum ought now to be opened by division of the remains of the corpus callosum and fornix in the middle line, and it may be followed in its whole extent to the extremity of the descending cornu. By this proceeding the veins of Galen will be traced back through the velum interpositum to the margin of the tentorium, and, on division of the velum, the valve of Vieussens and the origin of the fourth nerve, as well as that of the optic tract, may be seen; but if the view of these objects should not be satisfactory, they may be again examined after removal of the brain from the skull.

The remaining part of the brain is to be removed by cutting the tentorium on each side sufficiently to allow the cerebellum to be raised, and dividing the spinal cord and vertebral arteries as low as possible, the spinal accessory and suboccipital nerves, and the cranial nerves in order from behind forward, with the infundibulum and internal carotid arteries; after which the brain is to be laid on a flat plate with the base uppermost. If, however, it has been decided to remove the brain entire from the body, this may either be done in the manner now described, or, with the subject temporarily placed for the purpose on its back. According to the latter mode of procedure, which is the most customary, the anterior lobes of the brain are gently raised, and the olfactory bulbs lifted from the surface of the ethmoid bone; the optic nerves, internal carotid arteries, the infundibulum, and the third pair of nerves are successively divided; the anterior attachment of the tentorium is then to be cut on each side so as to secure the divisions of the fourth pair of nerves before they have any chance of being torn. The tentorium is then to be more extensively divided, and after it, in their order, the remaining nerves, the vertebral arteries, and the spinal cord. In studying the base of the brain, the distribution of the arteries should be first observed, with their union in the circle of Willis (p. 363). After they are removed, and the less adherent portions of the

arachnoid membrane and pia mater are stripped off, except from the angle between the cerebellum and medulla oblongata, the principal parts of the brain visible from the base are to be examined. These are:—the fissure of Sylvius separating the anterior from the middle lobe, and contained in it the hidden convolutions or island of Reil; at the entrance of the fissure the locus perforatus anticus, and terminating in it the inferior part of the transverse fissure of the cerebrum; also, the crura cerebri emerging from before the pons Varolii, the anterior extremity of the corpus callosum lying in the bottom of the great longitudinal fissure, and below it, proceeding backwards in the middle line, the lamina cinerea, the optic commissure, the tuber cinereum, the infundibulum, the corpora albicantia, and the locus perforatus posticus (p. 536). The principal objects to be noted on the medulla oblongata are the anterior pyramids with their decussation and the olivary bodies on the front, and the restiform bodies on its lateral aspect; posteriorly are the posterior pyramids, and the calamus scriptorius, and its prolongation downwards into the minute remains of the central canal of the spinal cord (p. 514). The fourth ventricle, situated between the medulla oblongata and cerebellum, is now brought into view, and at its sides will be observed the fringes of pia mater called choroid plexus of the fourth ventricle, the two small lobules of the cerebellum at the sides of the medulla oblongata named the flocculi or sub-peduncular lobes, and behind them the amygdalæ; while above the medulla are the parts belonging to the middle lobe of the cerebellum, afterwards more fully noticed (p. 521).

The origins of the cranial nerves may next be examined. The first pair or olfactory tracts and bulbs are seen on the anterior lobes, and should be traced back to the white striæ by which they arise at the inside of the fissure of Sylvius; the second and fourth nerves are seen passing round the crura cerebri, the optic tracts from the corpora quadrigemina, optic thalami and corpora geniculata, the fourth nerve from the valve of Vieussens; the third pair lying close together on the inner aspects of the crura cerebri; the fifth pair emerging by two roots from the front of the pons Varolii; the sixth in front of the anterior pyramids; the seventh nerve in two parts, the portio dura and portio mollis, in the angle between the medulla oblongata, pons Varolii and cerebellum; the eighth pair in three parts, the glosso-pharyngeal, vagus or pneumo-gastric and spinal accessory, in front of the restiform body; the ninth pair in front of the olivary body; and the suboccipital (or first cervical nerve of some authors) close below the ninth (p. 583). The cerebellum is to be separated from the structures to which it is attached by division of its superior, middle and inferior crura. The general disposition of its convolutions and the superior vermiform process will be noted, as also the parts entering into the formation of the inferior vermiform process lying in the vallecula beneath, viz., the pyramid, uvula, and laminated tubercle, together with the posterior velum. Sections of the cerebellum are to be made to exhibit the arbor vitæ and the grey centre known as the corpus dentatum or rhomboideum. In conclusion, sections may be made of the pons Varolii to show its transverse and longitudinal fibres, of the medulla oblongata to show the olivary nucleus or corpus dentatum, and of the crura cerebri to show the locus niger.

The venous sinuses, arteries, and nerves in the base of the skull, ought now to be examined, if there is time, before the subject is turned on its back. The superior longitudinal sinus, the inferior longitudinal and the straight sinus (with the veins of Galen entering it), and the posterior occipital sinus are to be traced to the torcular Herophili; and the

lateral sinuses from that point to the jugular foramina. The cavernous sinuses, joined together by means of the circular sinus, are then to be opened; and the superior and inferior petrosal sinuses, and the transverse sinus (p. 461). In the vicinity of the cavernous sinus the relations of the 3rd, 4th, 5th, and 6th nerves are to be exhibited, and also the internal carotid artery and the Gasserian ganglion (pp. 594 and 359); after which the nerves are to be replaced in situ and protected with cotton dipped in spirits, that they may be ultimately traced forward in the dissection of the orbit. The pituitary body is to be removed from its position in the sella turcica, and its form and structure examined (p. 539).

If the above examination of the sinuses cannot be accomplished, at this stage of dissection, the interior of the skull must be carefully cleaned, and protected from the air by replacing the skullcap or otherwise. The dissectors must also attend to the preservation of the parts at the back of the neck before the subject is turned.

3.—*Cervical Region superficially, and Posterior Cervical Triangle.*—It is essential that within four days after the subject has been laid upon its back, the dissection of the posterior and inferior triangle of the neck be completed, so that the third part of the subclavian artery may be seen to advantage before the clavicle and the vessels and nerves of the superior extremity are divided.

With this view, a superficial dissection is advised of the whole cervical region. Make an incision in the middle line from the sternum to the chin; another from the acromion, along the clavicle, to the sternum; and a third from the chin to the back of the ear; and let the flaps so obtained be reflected backwards; care being taken not to injure the fibres of the platysma myoides, nor the nerves which lie in the superficial fascia. The platysma is to be examined and reflected upwards (p. 178); after which, let the external and anterior jugular veins be laid bare, and also the cutaneous branches of the cervical plexus of nerves, viz.:—superiorly, the superficial cervical, great auricular, and small occipital nerves; and, inferiorly, the suprasternal, supraclavicular, and supraacromial nerves: these will be traced most easily from their line of emergence at the posterior border of the sterno-mastoid muscle (pp. 459 and 638). Let the disposition also be noted of the deep cervical fascia (p. 197).

The dissector will then cut down through the fat at the lower part of the posterior border of the sterno-mastoid muscle, and uncover the omo-hyoid muscle, whose posterior belly emerges from behind the sterno-mastoid, and forms the superior boundary of the inferior division of the posterior triangle. He will remove the fat and lymphatic glands from the inferior triangle, until the scalenus anticus muscle is reached, which will serve as a guide to the third part of the subclavian artery and vein, and the superior trunks of the brachial plexus of nerves (pp. 366 and 643). Besides these structures, the dissector will observe, while engaged with this space, if the sterno-mastoid muscle is narrow, the phrenic nerve upon the surface of the scalenus anticus muscle; he will find the suprascapular nerve and the small branch to the subclavius muscle both coming from the trunk formed by the fifth and sixth nerves, the transverse cervical and suprascapular arteries, and part of the scalenus medius and posticus muscles, as well as the lower set of the chain of lymphatic glands which lie along the line of the sterno-mastoid muscle (pp. 644 and 499). The superior part of the posterior triangle is next to be dissected by clearing the upper attachments of the scaleni muscles, with the splenius colli and levator scapulæ (p. 177), when

the arrangement of the cervical plexus will be seen, together with the origin of the phrenic nerve (p. 636); also the spinal-accessory nerve emerging from the substance of the sterno-mastoid muscle, and forming connections with the cervical plexus before it disappears beneath the trapezius muscle (p. 625). The seven cervical and first dorsal nerves are to be cleaned up to their emergence from the intervertebral foramina, the communicating branches of the sympathetic nerve being preserved if possible (p. 691); and the posterior thoracic nerve and the branch to the rhomboid muscles are to be found (p. 643).

4. *Anterior Triangle and Deep parts of the Neck.*—Let a dissection of the deep fascia and of the sterno-hyoid and sterno-thyroid muscles be made in the middle line between the larynx and sternum, to exhibit the relations of the trachea as connected with the operation of tracheotomy (p. 888), in particular noticing the position of the innominate artery, the common carotid arteries, the thyroid body, the inferior thyroid veins, and the arteria thyroidea ima, if it be present (pp. 340 and 920). The dissection of the anterior triangle of the neck is now to be proceeded with, by cleaning the whole of the sterno-mastoid, sterno-hyoid and sterno-thyroid muscles, and the anterior belly of the omo-hyoid muscle (p. 191); and in front of the sheath of the great vessels the descendens noni nerve, with its twigs to the three last named muscles, is to be laid bare (p. 626). Let the sheath of the vessels be opened, and the upper part of the common carotid artery exposed, with the pneumo-gastric nerve and internal jugular vein beside it; mark the place of its division into external and internal carotid arteries, and examine the first part of these two vessels, following the external carotid up to the parotid gland. Let the digastric and stylo-hyoid muscles be cleaned, and the parts be exposed in the submaxillary triangle, viz., the superficial part of the submaxillary gland, the submental branch of the facial artery, and the mylo-hyoid muscle, with the nerve that supplies it (pp. 183 and 608); observe also the ninth cranial or hypoglossal nerve lying close to the stylo-hyoid muscle, and dissect out its branch to the thyro-hyoid muscle (p. 627).

The sterno-mastoid muscle is to be divided about three inches from its upper end, and the superior part is to dissected quite up to the bone, care being taken not to cut the spinal accessory nerve which pierces it. The sterno-hyoid and sterno-thyroid muscles ought now to be divided near their lower end, the thyroid body dissected, and its form and relations noted. The dissector will then direct his attention to the branches of the external carotid artery; he will dissect the superior thyroid artery and note its sterno-mastoid branch (already cut), and the hyoid, laryngeal, and crico-thyroid branches; he will dissect also the commencement of the ascending pharyngeal artery, the occipital artery as far as the occipital groove of the temporal bone, the posterior auricular artery, the lingual artery as far as the border of the hyoglossus muscle, and the facial artery as far as the lower jaw (p. 346); he will also lay bare the pneumo-gastric nerve as far as convenient, tracing the superior and external laryngeal branches (p. 622).

In the lower part of the neck, the subclavian artery is now to be examined in the three parts of its course; and the different relations of the subclavian and common carotid arteries in the first part of their courses on the two sides of the body are to be carefully compared (p. 364). The internal jugular and the subclavian veins, with the branches entering them, are to be dissected, and on the left side the arched part of the thoracic duct descending into the angle of junction of these two veins (pp. 459, 469, and 488). The branches of the subclavian artery are to be displayed, viz., the ver-

tebral and internal mammary arteries, the thyroid axis, from which arise the inferior thyroid giving off the ascending cervical artery, the suprascapular artery, and most frequently the transverse cervical dividing into the superficial cervical and posterior scapular; lastly, there are the deep cervical and superior intercostal arteries coming off either as a single trunk or separately (p. 366). The frequent origin of the posterior scapular artery from the third part of the subclavian artery and other varieties will here require to be attended to (p. 372). The trunk of the sympathetic nerve is to be dissected, with its three cardiac and its other branches, as high as the first cervical nerve (p. 688); and the recurrent laryngeal branch of the vagus nerve is to be found between the gullet and trachea, and traced up to the larynx (p. 622).

5. *Superficial Dissection of the Face.*—In proceeding with this region, the dissectors ought to expose in concert the superficial muscles of the face on one side, keeping only the principal blood-vessels and nerves. They ought likewise to make a more detailed exposure and dissection of these vessels and nerves on the other side, for which purpose the superficial muscles must be in some measure sacrificed. If this method cannot be followed in concert, each dissector must display as much as possible all the parts on his own side, in which case he will do best to begin with the superficial muscles.

To exhibit the superficial muscles of the face, the skin is to be reflected from the middle line, from which one or two such transverse incisions as shall seem necessary are to be directed outwards. It is most convenient to begin with the orbicularis palpebrarum muscle, removing the skin from the circumference to the margin of the eyelids, and dividing it along these margins (p. 171). The muscles between the eye, nose and upper lip may then be exposed, the principal of which are these :—the compressor naris, the levator labii superioris alæque nasi, the levator proprius labii superioris, and the zygomatici, more deeply the corrugator supercilii, the levator anguli oris, the pyramidalis nasi continued from the frontalis, the dilatator naris, &c. Below the mouth the depressor anguli oris and depressor labii inferioris will be seen. A more complete view of the orbicularis oris may be obtained by dissecting it from the inner aspect of the lips; and the levator menti is best displayed by making an incision down to the bone in the middle line, and dissecting outwards.

To expose the nerves and blood-vessels of the face, the skin may be reflected as stated above from the middle line outwards. The surface of the parotid gland is to be cleaned, and search made for the branches of the facial nerve as they emerge from underneath its upper and anterior margins (p. 614). The duct of the parotid gland, and the transverse facial artery are also to be dissected (p. 354). The branches of the facial nerve are to be followed forward, and, as far as possible, their connections with the infraorbital, buccal and inferior labial branches of the fifth nerve are to be traced. Let the dissector cut the superior attachment of the levator proprius labii superioris muscle, and dissecting down upon the infraorbital foramen, follow out the distribution of the infraorbital nerve and artery emerging from it (pp. 602 and 357). Let him also cut carefully down upon the mental foramen, and follow out the inferior labial nerve and artery emerging thence (p. 608).

The facial artery and vein with their branches are to be dissected out from the point to which they have been previously traced at the border of the jaw. The principal branches of the artery, such as the inferior labial,

the superior and inferior coronary, the lateral nasal and the angular, are to be exposed (p. 350).

The branches of the facial nerve should be traced backwards through the parotid gland to the emergence of the main trunk from the stylomastoid foramen: while this is being done, the connections of this nerve with the auriculo-temporal branch of the fifth and with the great auricular nerve will be preserved, and the twigs to the posterior belly of the digastric muscle and the stylo-hyoid muscle should be sought for, close to the skull (p. 613). The continuation of the external carotid artery into the superficial temporal will be seen; and in dissecting out the remains of the parotid gland, the position and relations of that gland can be studied (p. 814). In this part of the dissection the student should also observe the connections of the part of the cervical fascia which separates the parotid and submaxillary glands, and which is continuous with the strong band known as the stylo-maxillary ligament (p. 197). Finally, the dissector may clean and examine the tarsal and nasal cartilages (pp. 706 and 771).

6. *Deep Dissection of the Face.*—The masseter muscle, and the nerve and artery which enter its deep surface from the sigmoid notch of the lower jaw are to be examined (p. 181), and the temporal fascia removed, the orbital twig of the superior maxillary nerve being sought between its layers (p. 600). By means of the saw and bone-nippers, the zygomatic arch may then be divided in front and behind in such a manner as exactly to include the origin of the masseter muscle, which should be turned downwards and backwards, the masseteric nerve and artery being in the meantime preserved. Let the coronoid process be divided by a vertical and horizontal incision with the saw and nippers as low down as possible, care being taken not to cut the buccal nerve, which lies in close contact with the temporal muscle. The coronoid process with the temporal muscle attached is to be reflected upwards, and the neck of the jaw is to be divided a little below the condyle, and as much of the ramus of the jaw is to be removed as can be cut away without injury to the inferior dental artery and nerve which enter the foramen. The internal maxillary artery with its branches is to be exposed as far as can be done without injury to the external pterygoid muscle, on whose outer surface it generally lies; it is frequently, however, covered by it. The gustatory and inferior dental nerves will be seen below the inferior border of the external pterygoid muscle, the latter nerve giving off the mylo-hyoid branch before entering the inferior dental canal, and resting on the fibrous slip commonly known as the internal lateral ligament of the jaw, between which and the jaw the internal maxillary artery likewise passes. Above the superior border of the same muscle will be seen the anterior and posterior deep temporal arteries and nerves, and between the two parts of the same muscle, the buccal nerve and vessels. After the external pterygoid muscle has been examined (p. 182), the temporo-maxillary articulation is to be studied (p. 132), and opened by cutting the external lateral ligament and dividing the capsule of the joint above and below the interarticular fibro-cartilage, and the condyle of the jaw is to be disarticulated; care being taken not to cut the auriculo-temporal division of the inferior maxillary nerve, which is in close contact with the inner side of the capsule (p. 606). The external pterygoid muscle may now be turned forward along with the head of the jaw, and its nerve found; after which it may be removed.

The branches of the internal maxillary artery in the vicinity of the pterygoid muscles are thus brought fully into view, viz.: in the first part of its

course, the inferior dental, the middle meningeal giving off the small meningeal artery, the two deep temporal, the pterygoid and other muscular branches: next, more deeply within the pterygoid muscles, the posterior superior dental and the infraorbital branches (p. 354). The chorda tympani nerve is to be dissected upwards to the fissure of Glaser, from its point of junction with the gustatory nerve under cover of the external pterygoid muscle, and the branches of the inferior maxillary nerve are to be traced back to the foramen ovale (p. 605): the auriculo-temporal nerve will frequently be found embracing the middle meningeal artery. The internal pterygoid muscle is to be examined as far as it can be laid bare (p. 181). The auriculo-temporal division of the inferior maxillary nerve is then to be traced to its distribution, and the pinna of the ear is to be dissected so as to show the form and extent of its cartilage, the small muscles on its surface, and the final distribution of its nerves (p. 741).

7. *The Orbit.*—The dissection of the orbit and the parts passing into it may next be proceeded with. Let a vertical cut be made with the saw through the frontal bone, near the inner angle of the orbit, immediately above the fovea trochlearis; and another from above the ear, downwards and forwards, through the lateral wall of the skull, towards the sphenoidal fissure. Remove the outer part of the malar bone with the bone-nippers, separate carefully with the handle of the knife the periosteum and contents of the orbit from the upper and outer walls, and unite the inner saw-cut with the sphenoidal fissure, immediately outside the optic foramen, by means of the chisel; then, with the bone-nippers, remove the isolated piece of bone so as to unroof the orbit, and afterwards divide the periosteum longitudinally, and reflect it. On the upper surface of the contents of the orbit posteriorly is the fourth nerve, which is to be traced forwards from the cavernous sinus where it enters the orbital surface of the trochlearis muscle, and that muscle is to be displayed (pp. 594 and 179). The frontal nerve, occupying the middle of the space, is to be traced back to its origin from the ophthalmic division of the fifth nerve (p. 597). The lachrymal gland is to be exposed (p. 709); and from its posterior border the lachrymal nerve is to be traced back to its origin from the ophthalmic nerve, while at the same time its malar branch and palpebral distribution may also be seen. The levator palpebræ muscle, and the inferior, external and internal recti muscles are to be displayed (p. 179), and the ocular surface of each cleared; when the sixth nerve will be seen ending in the external rectus, and branches of the third in the other three recti muscles. These nerves are now to be traced backwards between the two heads of origin of the external rectus muscle to the cavernous sinus (pp. 593 and 610). Below the superior rectus muscle the nasal nerve, derived from the ophthalmic, will be seen crossing the optic nerve; it will be followed to the anterior internal orbital foramen, and its infratrochlear branch traced to the lower eyelid; it is then to be dissected back to its origin, and the long and delicate root of the lenticular ganglion sought for on the outer side of the optic nerve. The ophthalmic or lenticular ganglion is on the outside of the optic nerve, and may be most easily found by tracing the short and thick twig which runs into it from the inferior division of the third nerve. In front of the ganglion its ciliary branches may be seen (p. 599). The remainder of the fat is to be removed from the lower part of the orbit; the distribution of the ophthalmic artery is to be displayed (p. 360); and the lower division of the third nerve is to be traced forwards to the inferior rectus and obliquus muscles. By a slight dissection from the front

of the orbit the insertions of these muscles may be more fully displayed. The contents of the orbit may be afterwards divided behind and turned forward, to admit of the tensor tarsi muscle and the lachrymal sac being dissected. Finally, if the subject be favourable, the nasal nerve may be traced through the ethmoid bone to its distribution in the interior of the nares, and its external twig to the tip of the nose examined.

8. *Deep view of the Fifth Nerve. Spheno-palatine and Otic Ganglia. Internal Ear.*—After the dissection of the orbit has been completed, the foramen rotundum and infraorbital canal are to be laid open, and the superior maxillary nerve and its orbital and dental branches dissected (p. 600). Remove with the saw a further portion of the skull towards the meatus externus, reaching as far as the foramen spinosum, and with the chisel or nippers cut down close to the foramen ovale; remove also a portion of the bone above the pterygoid processes so as to open up the spheno-maxillary fossa, and the spheno-palatine ganglion will be brought into view. The connection of the ganglion with the superior maxillary nerve may then be made out. Trace the nasal and naso-palatine branches of the ganglion through the spheno-palatine foramen, and the palatine branches passing downwards. Lay open the Vidian canal and dissect the Vidian nerve back to the great superficial petrosal nerve (p. 603). At the same time the infraorbital, spheno-palatine, descending palatine and Vidian branches of the internal maxillary artery will be noted (p. 356). The otic ganglion may also be in part seen by breaking open the foramen ovale, following upwards the nerve of the internal pterygoid muscle, and slightly everting the trunk of the inferior maxillary nerve (p. 608). The twigs from this ganglion to the tensor palati and tensor tympani muscles may be found. The otic ganglion, however, can only be seen to advantage in dissections made from the inner side of the internal pterygoid muscle and inferior maxillary nerve. The Eustachian tube may be laid bare in the posterior part of its course, and may be opened, and the attachment of the tensor tympani above it shown (p. 747).

By now sawing the wall of the skull down to the margin of the external auditory meatus, and removing with the bone-nippers, cautiously, the anterior wall of the meatus externus, the membrana tympani may be exposed; and by unroofing the tympanic cavity in continuation of the Eustachian tube backwards, the malleus, incus and stapes, as well as the tendon of the tensor tympani muscle will be brought into view (p. 748). The mode of action of the latter on the membrana tympani may be studied; also the chorda tympani nerve will be seen traversing the cavity. The malleus and incus are to be carefully removed; then, placing one point of the bone-nippers in the internal auditory meatus, lay open with the other the vestibule and cochlea, and let the relation of the portio mollis and portio dura nerves to these cavities be observed (pp. 610 and 615). The manner in which the stapes fits into the fenestra ovalis may now be seen to advantage, the tendon of the stapedius muscle requiring, however, to be cut across before that ossicle can be removed. With the aid of the bone-nippers, the fleshy part of the stapedius may be laid bare, descending in the mastoid part of the temporal bone, close to the facial nerve; and, in favourable circumstances, the corda tympani may be traced back to the facial nerve.

9. *Submaxillary and Sublingual Regions.*—Let the lower jaw be divided in front of the masseter muscle, and let the gustatory and mylo-hyoid nerves be followed from the pterygoid into the submaxillary region. The

anterior belly of the digastric muscle is to be divided at the chin and turned down. The mylo-hyoid muscle is to be separated from its fellow in the middle line and from the hyoid bone, and reflected toward the jaw, in order to expose the deeper parts. The tongue is to be put on the stretch by fastening it forward; the lower jaw is to be divided by a vertical saw-cut between the first and second incisor teeth, leaving intact the attachment of the genio-hyoid muscle; the fragment of loose bone is to be raised, and the mucous membrane of the mouth slit up to the tip of the tongue. The dissector will first trace carefully out the gustatory nerve, where it is in contact with the submaxillary gland, and will exhibit the submaxillary ganglion connected with it (p. 609). He will then isolate the submaxillary and sublingual glands, and will observe the relations of Wharton's duct, the sublingual ducts, and the gustatory and hypoglossal nerves (p. 816). He will examine the hyoglossus muscle, the genio-hyoid, the genio-hyoglossus, stylo-glossus, and stylo-pharyngeus muscles (p. 185); also the glosso-pharyngeal nerve (p. 615), and the stylo-hyoid ligament (p. 52). On dividing the hyo-glossus muscle, the subjacent part of the lingual artery may be followed into its sublingual and ranine branches; its small hyoid branch and its branch to the dorsum of the tongue may also be seen; as well as those deep branches of the facial artery which have not yet been examined, viz., the ascending palatine and the tonsillar branches (p. 348).

10. *Parts close to the external basis of the Cranium.*—If the styloid process be nipped through at its base and thrown down with the three styloid muscles attached, the dissector will be enabled to examine more particularly the pharyngeal plexus of nerves (p. 690). He may then also examine the relations of the internal carotid artery and internal jugular vein (p. 359): and he will follow up the hypoglossal, spinal-accessory, pneumo-gastric, glosso-pharyngeal, and sympathetic nerves to the basis of the skull; examining the connexions of the superior ganglion of the latter with the other nerves mentioned, and with the anterior divisions of the upper cervical nerves (p. 620). The jugular foramen and the carotid canal are to be opened into; and the eighth nerve, and the internal carotid artery with the carotid plexus accompanying it, are to be followed into the interior of the cranium (pp. 619 and 688). Before leaving this part of the dissection, the students dissecting the head ought to make together a complete revision of all the parts in connexion with the basis of the cranium.

11. *Pharynx, Larynx, Palate, Tongue, Nares, &c.*—Let the remains of the carotid arteries be removed, and the pharynx drawn away from its loose connection with the upper cervical vertebræ; and let the base of the skull be divided between the pharynx and the recti capitis antici muscles; then, leaving the neck and back part of the skull for a later examination, let the pharynx, with the parts in its vicinity, be prepared for dissection by distending its walls with hair or tow. The constrictor muscles of the pharynx are to be cleaned and examined, as also the origins of the levator and circumflexus palati muscles (p. 187). The next step is to open the pharynx from behind, by an incision in the middle line, and a transverse one close to the base of the skull; and to examine the apertures of the nares, fauces, glottis, œsophagus, and Eustachian tubes (p. 819). The muscles of the soft palate are then to be dissected; more particularly the insertions of the levator and circumflexus palati; the palato-pharyngeus and palato-glossus corresponding in position to the posterior and anterior pillars of the fauces, and in the middle line the azygos uvulæ (p. 189). The Eustachian tube should also be dissected out.

The larynx and tongue are to be separated from the upper jaw, and the surface of the tongue and the tonsils examined, as well as such of the intrinsic muscles of the tongue as may be visible (p. 805). The dissectors will then proceed to the study of the larynx, carefully cleaning it (p. 905); and after the glottis and true and false vocal cords have been sufficiently inspected, they may remove the mucous membrane, tracing at the same time the distribution of the superior and inferior laryngeal nerves, and the laryngeal branch of the superior thyroid artery. The muscles of the larynx will then be fully dissected. The crico-thyroid, the arytenoid, the aryteno-epiglottidean, and the posterior crico-arytenoid muscles can be seen without injuring the cartilages; but to expose the lateral crico-arytenoid and the thyro-arytenoid muscles, it is necessary to remove the upper part of one ala of the thyroid cartilage. Lastly, the ventricles and pouches of the larynx are to be examined, the vocal ligaments are to be dissected out, and, the muscular substance having been removed from the cartilages, their uniting ligaments, and the joints by which they move on one another, are to be studied.

In concluding this stage of the dissection, let a vertical section of the nares and hard palate be made on one side of the septum nasi. Let the meatus of the nose, the nasal duct, and the maxillary antrum be examined (p. 773); and, if the subject is in good condition, a view may be obtained of the palatine and naso-palatine branches of the spheno-palatine ganglion, as well as of the distribution of the descending palatine artery in the palate (pp. 603 and 357).

12. *Deep Muscles and articulations of the Neck and Head.*—The muscles attached to the cervical vertebræ are now to be examined. In front of the vertebral column, the student will observe the scaleni, longus colli, recti capitis antici major and minor, and rectus lateralis muscles (p. 193); then turning to the posterior aspect, he will dissect the remains of the levator anguli scapulæ (p. 203), splenius, trachelo-mastoid and complexus muscles to their attachments (p. 234), and notice the portion of the occipital artery covered by the splenius, with its branch the princeps cervicis (p. 351). The recti capitis postici major and minor, and the obliqui capitis superior and inferior, with the suboccipital nerve supplying them, are to be dissected out (pp. 239 and 632), and the course of the vertebral artery displayed as it lies in the groove of the atlas (p. 367). Lastly, the arches of the vertebræ are to be removed, and the joints and ligaments examined, especially those between the atlas, axis, and occipital bone, among which the transverse ligament of the atlas and the crucial and odontoid ligaments require particular attention (p. 125).

II.—UPPER LIMBS OR SUPERIOR EXTREMITIES.

The right and left limbs constitute each a part. Their dissection should extend over a period of not less than four weeks. They each include, along with the limb itself, the axilla or armpit, and the structures which lie between the trunk of the body and the bones of the shoulder and arm. The muscles of the back and the spinal cord are also to be dissected by those having the upper limbs. The omo-hyoid muscle, however, and the upper parts of the trapezius, levator anguli scapulæ, splenius, trachelo-mastoid, and complexus muscles should be left uninjured for the dissectors of the head and neck. The inferior boundary of this part on the trunk of the body is indicated by a line passing along the

outer and lower borders of the latissimus dorsi, the serratus magnus, and the pectoralis major muscles.

1. *Muscles of the Back; Spinal Cord.*—During the first four days, while the subject is lying on its face, the dissection of the back and spinal cord below the level of the third cervical vertebra is to be completed. Let an incision be made in the middle line from the level of the third cervical vertebra to the sacrum, a second from the acromion to the spine of the seventh cervical vertebra, and a third from the point where the fold of the axilla meets the arm to the acromion. If the student be a beginner, let him at once dissect out the trapezius muscle in the direction of its fibres (except the part of it which falls within the boundary of the dissection of the head and neck), and afterwards the latissimus dorsi, following up its fibres as close as possible to the tendon of insertion; but let him not reflect the skin further than is necessary to exhibit the anterior border of the latissimus dorsi (p. 200). If the student be a senior, he will, previous to the dissection of these muscles, also display the cutaneous branches of the posterior divisions of the spinal nerves, which lie upon their surface (p. 633).

The trapezius muscle is to be divided by a vertical incision at the distance of two inches from its vertebral attachment, and on its deep aspect the spinal accessory nerve and the superficial cervical artery are to be displayed (pp. 625 and 373). The rhomboid and levator anguli scapulæ muscles may then be dissected (pp. 202 and 643), and the nerve to the rhomboids, reaching their deep surface from above. The latissimus dorsi muscle is to be divided by means of an incision carried along its attachment to the lumbar fascia from its superior border, at about three inches from its vertebral attachment, downwards and outwards towards the external border, leaving uncut the slips attached to the lower ribs and crest of the ilium. The rhomboid muscles are also to be divided, and the posterior scapular artery dissected (p. 373). The serrati postici superior and inferior muscles may then be dissected, and the vertebral aponeurosis seen (pp. 233 and 240); after which a view may be obtained of the serratus magnus muscle from its internal aspect (p. 207).

The posterior serrati muscles and the vertebral aponeurosis may now be divided, and the dissection of the muscles composing the erector spinæ may be proceeded with (p. 234). Beginning with the ilio-costalis or sacro-lumbalis muscle, the student will dissect first its six or seven slips of direct insertion into the lower ribs, then the slips attached to the upper ribs, constituting the musculus accessorius ad ilio-costalem: he will afterwards turn the muscle outwards and trace the separate heads of origin of the musculus accessorius from the lower ribs into their insertions above; and also the similar origins of the ascendens cervicis muscle from the upper ribs. He will next treat the longissimus dorsi muscle in the same manner, dissecting first the costal insertions on its outer side, and then, having separated it from the spinalis dorsi muscle (which always requires the division of a tendon running between the two muscles), make out the insertions into the transverse processes of the vertebræ. The issue of posterior branches of spinal nerves, and of intercostal and lumbar vessels, will guide the dissector to the separation of the masses of muscle (pp. 633 and 404). The continuation of the long muscles into the ascendens cervicis and transversalis cervicis, and the origins of the trachelo-mastoid, are then to be traced upwards in the neck. To see the last-named muscle, however, the splenius muscle must be dissected and vertically divided; and the complexus and

semispinalis dorsi and colli muscles may then be examined. Lastly, the deepest muscles, multifidus spinæ, rotatores spinæ, inter-spinales, and inter-transversales are to be dissected (p. 238).

At this stage of the dissection a good view may be obtained of the posterior margins of the obliquus externus and obliquus internus muscles of the abdomen, and of the posterior and middle layers of the lumbar aponeurosis, which are continuous behind with the transversalis muscle: the dissection of these muscles, however, belongs to the abdomen, and they must not be injured (p. 199).

The next proceeding for a senior dissector is to lay bare the spinal cord; for this purpose he will straighten as much as possible the lumbar vertebræ, by placing blocks underneath the abdomen, and will let the neck hang slightly downwards. He will then saw through the laminæ of the dorsal and lumbar vertebræ on each side, keeping the edge of the saw directed slightly inwards, and will continue the saw-cuts below on the back of the sacrum, so as to meet each other where the sacral canal becomes incomplete. The part so isolated may easily be raised with the chisel, and with the bone-nippers the whole laminæ of the vertebræ may be removed, attached to one another by their elastic ligaments. In several spaces of the lower dorsal region the articular processes of the vertebræ may be removed, so as to expose one or more of the spinal nerves issuing from the canal, and these, being dissected for a little distance beyond their ganglia, may be afterwards taken out along with the cord. The theca of dura mater ought now to be made as clean as possible by removing the fat from its surface, and, after being examined, should be slit open, that the other membranes and the relations of the cord may be examined in situ; more particularly, the ligamentum denticulatum, the position of the lower extremity of the cord, the cauda equina, and the filum terminale will be observed (pp. 502 and 565). The spinal cord and its membranes are then to be removed from the body and stretched out upon a table, when the anterior and posterior roots of the nerves and some of the ganglia in connexion with the latter may be observed; also the external form and structure of the cord, with the anterior, middle, and posterior columns, the anterior and posterior fissure, &c.; and, lastly, several sections of the cord, in different places, may be made to exhibit the relations of the grey and white matter within.

2. *Pectoral Region and Axilla.*—Within four days after the subject has been laid upon its back, the pectoral region and the axilla are to be dissected. Let a median incision be made in front of the sternum, and from its upper end let another be carried along the clavicle to the acromion, and thence downwards to the inside of the middle line of the arm, a little below the fold of the axilla, and a third horizontally outwards from the lower end of the sternum. Then let the skin be reflected from the pectoralis major muscle (p. 203), and let the senior student in doing this preserve the fibres of the platysma myoides and the suprasternal and supra-clavicular branches of the cervical plexus of nerves descending over the clavicle (pp. 170 and 639), the anterior cutaneous branches of the inter-costal nerves, with the accompanying twigs from the internal mammary artery near the middle line, and two or three small anterior twigs of the lateral cutaneous branches of the intercostal nerves appearing round the lower border of the muscle (pp. 656 and 375). If the subject be a female, let him also dissect the mammary gland, and in raising the general integument leave the skin of the nipple, by carrying a circular incision round it of about two inches in diameter (p. 1002). By raising the skin

within this circle the lactiferous ducts and sacculi will be brought into view.

Let the clavicular portion of the pectoralis major muscle now be divided near the clavicle for the examination of the subclavicular space, preserving the external anterior thoracic nerve as it passes to that muscle (p. 645); and let the costo-coracoid membrane and sheath of the axillary vessels be examined (p. 229). Then let the sheath be removed, and let the termination of the cephalic vein and the parts of the axillary artery and vein brought into view be studied, and also the superior or short thoracic, acromio-thoracic and thoracico-humeral branches (pp. 377 and 468).

For the dissection of the axillary space, the skin and the fascia are to be separately raised from its surface (p. 230), and in the first place the great vessels and nerves of the limb should be carefully exposed as they pass from the axilla into the brachial region, but without much disturbing their position. The axillary artery and vein are then to be followed upwards, and the fat removed from within the space, when the long thoracic vessels will be found chiefly along the anterior border, the subscapular vessels principally along the posterior border, and the alar twigs more in the middle. At this stage there will also be seen on the inner wall of the axilla the intercosto-humeral with other lateral cutaneous branches of intercostal nerves piercing the serratus magnus muscle (p. 657), the posterior thoracic nerve descending on the surface of that muscle to supply it (p. 644), and on the posterior wall the three subscapular nerves (p. 645). When the axilla has been sufficiently studied, the remainder of the pectoralis major muscle is to be divided; the pectoralis minor muscle also is to be dissected and divided, and the internal anterior thoracic nerve, which supplies it, is to be found. By this proceeding the axillary vessels will be exposed in their whole course, and the origins of the branches of the axillary artery may be more fully examined, viz., the acromio-thoracic, the alar thoracic, short and long thoracic, and subscapular arteries, and the anterior and posterior circumflex arteries. Three cords of the brachial plexus will also be seen; the outer one giving off the musculo-cutaneous, the external anterior thoracic, and the outer head of the median nerve; the inner giving off the inner head of the median nerve, the internal cutaneous nerve, the nerve of Wrisberg and the ulnar; the posterior giving off the three subscapular nerves, the circumflex, and the musculo-spiral nerve. At this time, after removing the costo-coracoid fascia, the subclavius muscle should be cleaned and examined (p. 206).

On the fourth day after the subject has been placed upon its back, the clavicle is to be sawn through the middle, or disarticulated at its sternal end, if this should be recommended by the Demonstrator. The dissector of the arm may then, in company with the dissector of the head and neck, on the same side, obtain a continuous view of the upper part of the brachial plexus, and trace the origins of the suprascapular and posterior thoracic nerves (p. 641). The axillary vessels and the main trunks of the brachial plexus of nerves are afterwards to be securely tied together opposite the outer border of the first rib, and divided above the ligature; the lower parts may subsequently be retained in position, by tying them to the portion of the clavicle left with the arm. The serratus magnus muscle may now be put upon the stretch, and should be fully studied before the removal of the arm (p. 207).

3. *Scapular Muscles, Vessels, and Nerves.*—After the arm has been removed, the first duty of the dissector is to clean the parts which have

been already laid bare, and to dissect all the cut muscles, so as to bring their attachments completely into view; he may then remove the redundant masses which are no longer required, preserving only such portions of tendons and muscles as may be necessary for subsequent revision of their relations to the joints and their attachments to the bones. He will then clean the deltoid muscle, beginning from behind, so as to save as much as possible the cutaneous branches of the circumflex nerve (pp. 208 and 645). He will dissect the teres major muscle, and the quadrangular and triangular intervals which are separated by the long head of the triceps muscle, and lie between the teres muscle and the scapula; and he will lay bare, as far as can be done without injury to the muscles, the structures which pass through these intervals, viz., in the upper or quadrangular one, the circumflex nerve, with its branch to the teres minor muscle, and the posterior circumflex artery, and in the lower or triangular interval, the dorsal branch of the subscapular artery (p. 380). The deltoid muscle is next to be removed from the whole of its superior attachment, and beneath it will be seen the bursa that lies between the acromion and shoulder-joint (p. 138), and the branches of the circumflex vessels and nerve. The teres minor, infraspinatus and supraspinatus muscles are to be dissected and reflected, and the distribution of the suprascapular nerve and artery traced. While this is done, neither the deltoid ligament nor acromion need be divided. The subscapular muscle is likewise to be examined, with the two short subscapular nerves which supply it; and on reflecting this muscle, the subscapular bursa will be observed communicating with the shoulder-joint. In removing the muscles attached to the scapula, the student should bring into view the anastomoses of the posterior scapular, suprascapular, acromio-thoracic, dorsal branch of the subscapular, and the circumflex arteries. The scapular muscles may then be cut short at their attachments to the humerus.

4. *Subcutaneous view of the Arm.*—In proceeding with the dissection of the arm, if the part be in a condition favourable for the purpose, the dissector may at once display the cutaneous nerves and veins as far as the wrist (p. 647). He will, in that case, make an incision all the way down to the wrist in front of the limb; or, should it be deemed advisable not to remove the integument so far, he may terminate his incision half-way down the fore-arm. For the easier preservation of the cutaneous nerves, which lie close to the aponeurosis of the limb, he will remove the subcutaneous fat by reflecting it in the direction from above downwards. The intercosto-humeral nerve is to be traced down to its distribution (p. 657). The nerve of Wrisberg and the internal cutaneous branch of the musculo-spiral nerve will be most easily traced from their deep origins (pp. 646 and 652). The internal cutaneous nerve will be found piercing the aponeurosis on the inside of the arm in two separate places, a few inches above the elbow; and on the outer side will be found the two external cutaneous branches of the musculo-spiral nerve, appearing in the line of the external inter-muscular septum; while at the bend of the elbow, towards the outer side, the musculo-cutaneous or external cutaneous nerve will be observed emerging from the deep parts. Near the elbow, on the inner side, there is a small lymphatic gland, and on the subcutaneous part of the olecranon a small synovial bursa. Further down, there may be seen on the inner side a cutaneous branch from the ulnar nerve, below the middle of the fore-arm; on the outer side the radial nerve becoming superficial two or three inches above the wrist; and in front the palmar cutaneous branch of the

median nerve immediately above the annular ligament. On the fore-arm will be found the radial, median and ulnar veins; in front of the elbow the median-cephalic and median-basilic veins, together with the deep median branch; and in the upper arm the cephalic and basilic veins (p. 466).

5. *Brachial Region more deeply.*—The student will now remove the aponeurosis from the front of the arm. He will first dissect out the brachial artery with the venæ comites clinging to it and inter-communicating round it, and the median nerve crossing in front (p. 381). Arising from the inner side of the artery he will find the superior profunda branch turning backwards with the musculo-spiral nerve, a little farther down the inferior profunda branch accompanying the ulnar nerve, and a little above the elbow, the anastomotic resting on the brachialis anticus muscle: while from the outer side of the brachial artery a variety of muscular branches are observed to spring. The inferior profunda sometimes arises from the superior profunda branch. Not unfrequently two large arteries will be found in the arm, in consequence of a high division of the main trunk; the radial or ulnar artery, most frequently the former, being given off from the brachial at a higher point than usual, and sometimes even as high as the axillary artery. In some of these cases the artery which arises out of place lies superficially to the aponeurosis of the limb. The biceps and coraco-brachialis muscles are next to be dissected, and the deep part of the musculo-cutaneous nerve, which gives them branches (pp. 212 and 648). The dissector will be careful to preserve the aponeurotic slip of insertion of the biceps, which lies superficially to the vessels at the bend of the arm. The aponeurosis is to be removed from the back of the arm, and the intermuscular septa are to be examined (p. 230): the triceps muscle is to be dissected, and the superior profunda artery and musculo-spiral nerve are to be traced to its outer side (pp. 214 and 652). The musculo-spiral nerve is to be followed to its division into the radial and posterior interosseous trunks, and its branches, to the brachialis anticus, supinator longus and extensor carpi radialis longior displayed. The space in front of the elbow should next be dissected, so as to show the relations in it of the brachial, ulnar, and radial arteries, with the radial recurrent and anterior ulnar recurrent branches, and the median and radial nerves (pp. 389 and 397). The brachialis anticus muscle should also at this time be fully exposed down to its place of insertion.

6. *Shoulder-joint, &c.*—The articulations at the upper part of the arm ought now to be examined (p. 134). The conoid and trapezoid parts of the ligaments uniting the clavicle to the coracoid process are first to be dissected, and their uses studied; then the acromio-clavicular articulation, and the suprascapular and coraco-acromial ligaments of the scapula; lastly, the shoulder joint is to be dissected, the capsule is to be cleaned, the coraco-humeral ligament dissected, and the tendons of muscles in close relation with the joint examined. When lastly the capsule is opened, the origin of the long head of the biceps in connection with the glenoid ligament will be seen, and also the prolongations of the synovial membrane round the long head of the biceps and beneath the subscapular muscle.

7. *The Fore-arm in front.*—Let the aponeurosis be removed from the front of the fore-arm, and let the five superficial muscles arising from the inner condyle of the humerus be dissected, beginning with the pronator radii teres; exhibiting its two heads of origin with the median nerve between

them, and proceeding successively to the flexor carpi radialis, palmaris longus (which, however, is often absent), flexor sublimis digitorum and flexor carpi ulnaris (p. 215); displaying the branches of the median nerve to the first four muscles, and that of the ulnar nerve to the last-mentioned muscle and to the flexor profundus digitorum (pp. 651 and 659). The course of the radial and ulnar arteries and nerves in the fore-arm is also to be studied. From the radial artery (p. 394) will be seen given off the radial recurrent, the muscular branches, the anterior carpal branch and the superficial volar; while arising from the ulnar artery (p. 388) will be seen the anterior and posterior ulnar recurrent, and the interosseous, dividing into anterior and posterior interosseous, and giving off the branch to accompany the median nerve. This last branch, the comes nervi mediani, derives importance from being not unfrequently developed as a third principal trunk of the fore-arm, which passes down into the superficial palmar arch. The muscular branches of the ulnar artery, and its anterior and posterior carpal branches, are also to be exposed. The deep layer of muscles, consisting of the flexor longus pollicis, flexor profundus digitorum and pronator quadratus, are next to be dissected (p. 219); and along with them, lying on the interosseous membrane, and giving twigs to the muscles, the interosseous branch of the median nerve, and accompanying it, the anterior interosseous artery (p. 390).

8. *The Hand in front.*—For the dissection of the front of the hand, let an incision be made down the middle of the palm, a second transversely through the skin above the division of the fingers, and others down the middle of each finger. Let the palmar aponeurosis be exposed (p. 231), preserving the palmaris brevis muscle which is attached to its inner margin (p. 225); and let the skin be reflected from the front of the fingers and thumb, so as to exhibit the sheaths for the tendons, and the two digital branches of the artery and nerve on each (p. 218). The palmar aponeurosis is then to be removed, and the trunks of the ulnar and median nerves will be brought into view (pp. 649 and 651), as also the ulnar artery, the superficial volar branch of the radial artery, and the superficial palmar arch (p. 393). The short muscles of the thumb, viz., the abductor, opponens, flexor brevis, and adductor pollicis, are to be dissected, with the twigs of the median nerve supplying the three first, and the insertion of the flexor longus pollicis; then the abductor, opponens, and flexor minimi digiti, with the twigs of the ulnar nerve supplying them, and its deep branch piercing them (p. 225). The annular ligament is to be cleaned and the synovial sheath behind it examined; the tendons of the superficial and deep flexors are to be followed to their insertions, and the lumbricales muscles dissected. The deep branch of the ulnar artery may now be traced to the deep palmar arch, and that of the ulnar nerve to its distribution in all the interossei, two of the lumbricales, the adductor pollicis and the inner part of the flexor brevis pollicis muscle. The deep palmar arch and its branches are also to be fully examined (p. 400).

9. *The Fore-arm and Hand Posteriorly.*—For the dissection of the back of the fore-arm and hand let the remainder of the integument and aponeurosis be carefully reflected, and let the distribution of the ulnar and radial nerves to the dorsal aspects of the fingers be traced (p. 653). The muscles are then to be dissected in the following order, viz., the supinator longus, extensores carpi radiales longior and brevior, extensor carpi ulnaris, extensor communis digitorum and extensor minimi digiti, the extensor indicis, the three extensores pollicis, and, lastly, the anconeus and supinator brevis muscles (p. 220). There will be found passing through the fibres

of the last-mentioned muscle, the posterior interosseous nerve; and on the interosseous membrane the posterior interosseous artery, with its recurrent branch; they are both to be traced to their distribution (pp. 654 and 391). The lower part of the radial artery which has hitherto been hid from view may also now be studied: its posterior carpal and its metacarpal branch will be seen, together with the dorsal branches of the thumb and index finger (p. 398). The termination on the back of the wrist of the anterior interosseous artery after passing through the interosseous membrane is also to be noticed. Finally, the interossei muscles are to be dissected on both the palmar and dorsal aspects of the hand (p. 227).

10. *Articulations of the Fore-arm and Hand.*—The dissector may now return to an examination of the elbow-joint and other articulations of the upper limb. In connection with the elbow-joint, he will first make a revision of the relations of the soft parts to the joint, such as those of the triceps, brachialis anticus and supinator brevis muscles, the muscles attached to the outer and inner condyles of the humerus, and the median, musculo-spiral and ulnar nerves, together with the anastomoses of the superior and inferior profunda and the anastomotic branches of the brachial, with the two ulnar, the radial and the interosseous recurrent arteries. The dissector will then proceed to examine in detail the internal and external lateral ligaments, the anterior and the thin posterior ligaments, the orbicular ligament, the synovial membrane, and the cartilaginous surfaces of the bones (p. 138). The dissector should carefully observe the different kinds of motion of which the parts are capable, and the variations in the tightness of the ligaments and in the relations of external parts induced by these motions. In examining the lower radio-ulnar articulation, the dissector will particularly study the relations of the triangular fibro-cartilage, and the nature of the movements in pronation and supination of the hand; and, in the carpal joints, the extent of the synovial cavities and the position of the cartilage and interosseous ligaments.

III.—THORAX.

The right and left sides of this region constitute each a part. Its dissection may be completed within three weeks. It includes the deep dissection of the thoracic parietes, the viscera of the thoracic cavity, together with the upper surface of the diaphragm. It is indispensable that the dissectors of opposite sides should be present together and act in concert.

1. *Parietes and Pleura.*—The dissection is to be commenced on the fifth day after the subject has been placed upon its back, that is, the tenth day after it has been first placed in the rooms. The external and internal intercostal muscles, and the intercostal arteries and nerves in the anterior part of their course, together with the parietal pleura, are to be first dissected (pp. 240, 402 and 655). Then let the internal mammary artery on the right side be laid bare by the removal of the 2nd, 3rd, 4th, 5th and 6th costal cartilages, in order that its relation to the sternum, and its anterior intercostal and perforating branches may be observed (p. 374). The corresponding costal cartilages on the left side may then be divided close to the ribs, and the ribs belonging to those cartilages on both sides are then to be divided as smoothly as possible about three inches beyond their angles; in doing which the dissectors must be careful to avoid injuring their hands upon the sharp spicula of the sawn extremities of the ribs. The anterior

limits of the pleural cavities and the position of the anterior mediastinum can now be examined, together with the position of the heart and great vessels in relation to the lungs and the walls of the thorax (p. 299). That this may be done more effectually, the lungs should be inflated through a tube introduced into the throat or wind-pipe, and their different positions and relations in the inflated and collapsed state attentively examined. The body of the sternum is next to be separated from the manubrium, and, together with the adherent costal cartilages of the left side, removed; and on the fragment of the thoracic wall thus separated the triangularis sterni muscle and its relation to the internal mammary artery may be further examined. The dissectors will then complete their examination of the anterior mediastinum, observing in its upper part the remains (if any) of the thymus body, and will carefully study the remaining reflections of the pleura. The heart within the pericardium is also to be observed (p. 313). In making this dissection the student may be required to separate the parietal from the pulmonary pleura, by breaking up with his fingers, or the handle of the knife, the inflammatory adhesions which are often met with. Great care must be taken to clean with a sponge and wash the interior of the chest and the surface of the lungs, first with water, and subsequently with preserving fluid (p. 892).

2. *Parts External to the Pericardium.*—The phrenic nerve will be seen on each side beneath the pleura in front of the root of the lung, and is to be dissected out; when its relation to the internal mammary artery, which it crosses at the upper part of the chest, and the branch of the latter artery which accompanies it, are to be observed (p. 640). The structures above the pericardium are then to be dissected. Foremost will be found the innominate veins and superior vena cava, with the termination of the vena azygos, and several smaller veins, viz., the inferior thyroid, internal mammary, superior intercostal, and bronchial veins (p. 453); and behind the veins, the innominate, left carotid, and left subclavian arteries arising from the arch of the aorta (pp. 340, 341 and 364). The pneumo-gastric nerves will also be found, that of the right side lying external to the innominate artery, and its recurrent branch turning round behind the subclavian artery; and that of the left side passing down in front of the arch of the aorta, with its recurrent branch winding behind the aorta (p. 618). Likewise crossing the arch of the aorta, on their way to the superficial cardiac plexus, will be found the cervical cardiac branch of the left pneumogastric nerve, and, usually, the superior cardiac branch from the sympathetic nerve on the left side (p. 690). The other cardiac nerves, viz., the cervical cardiac branch of the right pneumo-gastric nerve, the thoracic cardiac branches of both pneumo-gastric nerves, the three cardiac branches of the sympathetic chain of the right side, and the middle and inferior branches of the left side, are to be sought on the front and sides of the trachea, as they pass down to the deep cardiac plexus. The distribution of the pneumogastric nerves is then to be traced to the lungs and œsophagus; and, as far as possible, the posterior and anterior pulmonary plexuses are to be brought into view (p. 623). After that has been done, the roots of the lungs are to be fully dissected, the relations of the pulmonary arteries and veins and the bronchi observed, and the bronchial arteries traced to their origins (pp. 397 and 402).

3. *Interior of the Pericardium and Heart.* — The pericardium having been examined on its outer aspect, is then to be cut open, and its interior carefully inspected (p. 300); after which it is to be removed, its remains

being cleared away from the trunks of vessels entering and emerging from the heart. The arch of the aorta may now be fully studied, and the cord of the ductus arteriosus displayed passing between the commencement of the left pulmonary artery and the arch of the aorta (pp. 331 and 382). The students will then proceed to the dissection of the heart, examining first its external form (p. 302), and afterwards dissecting the right and left coronary arteries and the coronary vein (pp. 338 and 482). They will then make an opening into the right auricle, by means of one incision from the point of entrance of the vena cava superior to near the entrance of the vena cava inferior, and another from the auricular appendage to the middle of the first incision. They will remove and wash out the blood from the right side of the heart, and will particularly observe in the auricle the arrangement of the musculi pectinati, the annulus ovalis, the Eustachian valve guarding the vena cava inferior, the orifice of the coronary vein guarded by the valve of Thebesius, and the foramina Thebesii (p. 308). When the examination of the right auricle has been completed, the dissector will pass the forefinger of the left hand through the auriculo-ventricular orifice, and open the right ventricle by two incisions, one along the anterior border, close to the septum of the heart, prolonged upwards to the commencement of the pulmonary artery, and the other passing from the first, along the superior border of the ventricle, immediately below the auriculo-ventricular sulcus, care being taken not to injure the anterior segment of the tricuspid valve. The principal objects to be noted in this ventricle are the tricuspid valve with the chordæ tendineæ and musculi papillares which act upon it, the other arrangements of columnæ carneæ, the infundibulum, and the semilunar valves of the pulmonary artery on their cardiac aspect. In exposing the latter, the incision into the ventricle should be carried into the pulmonary artery between two of the segments of the valve (p. 310). To examine the left side of the heart, let the inferior vena cava be dissected a little out of its aperture in the diaphragm, and let it be divided, and the heart thrown upwards. The left auricle is then to be opened by a transverse incision near its ventricular margin, and by two short incisions at right angles to the first; and after being carefully sponged out, its cavity and auricular appendage, the remains of the valve of the foramen ovale, and the entrance of the pulmonary veins on each side will be examined (p. 311). The left ventricle is to be opened by a process similar to that employed for opening the right; and after it is carefully cleaned, the mitral valve and its relation to the aortic orifice, and the cardiac aspect of the semilunar valves which guard the latter are to be studied (p. 312).

4. *Deep Cardiac Nerves, Bronchi, &c.*—The aorta is to be divided within an inch above its origin, and the first part of the vessel is to be opened to examine the semilunar valves and the sinuses of Valsalva (p. 307). At this stage of the dissection a fuller examination may be made of the cardiac nerves as they enter the superficial and deep cardiac plexus: the cardiac ganglion will also be found, and the coronary plexus traced a short way along the coronary vessels (p. 698). The dissectors may then divide the trachea an inch or two above its bifurcation, remove the heart and lungs, and examine more in detail the disposition and structure of the bronchi (p. 888).

5. *Parts in the posterior mediastinum, &c.*—Returning to the thoracic cavity, the dissectors will examine the œsophagus (p. 821), the descending aorta with its intercostal branches (p. 401), the main vena azygos, and its left branch (p. 469) and, lying between the vena azygos and aorta, the thoracic

duct (p. 487). The thoracic duct may be followed, with the concurrence of the dissectors of the head and neck, to its termination in the angle of junction of the left internal jugular and subclavian veins ; and, with the assistance of the dissectors of the abdomen, it may be also followed down to its commencement under the crus of the diaphragm. The sympathetic nerve with its chain of ganglia, is now to be traced over the heads of the ribs and the vertebral column : its communications with the intercostal nerves are to be made out, and the splanchnic nerves arising from it dissected (p. 693).

The upper surface of the diaphragm having been cleaned with the knife, the dissectors of the thorax will examine along with those of the abdomen the anatomy of this muscle, directing their attention to its various muscular and tendinous parts, and to the apertures for the passage of the aorta, gullet, and vena cava inferior, and observing the distribution of nerves and blood-vessels in its substance (p. 243).

6. *Articulations.*—When the dissection of the rest of the thorax has been completed, the dissectors will, if the subject be favorable, make an examination of the articulations of the vertebral column and ribs (p. 121). Let them study, in particular, the anterior and posterior common ligaments, the intervertebral substance, the ligamenta subflava of the arches, the form and movements of the articular processes, and the various costo-vertebral, costo-transverse and other ligaments. In doing this, the dissectors should make an attentive examination of the nature and extent of the movements of the different ribs, and the manner in which they are influenced by the movements of the vertebral column.

IV.—ABDOMEN AND PELVIS.

The right and left sides of these regions constitute each a part. Their dissection should not be completed in less than four or five weeks. It comprehends the examination of the perinæum and genital organs, the abdominal parietes over the whole of the external oblique muscles, extending in front to the linea alba and below to Poupart's ligament, the viscera and deeper parts of the abdomen and pelvis, and the lower surface of the diaphragm.

1. *Perinæum.*—If the subject be a male, the first day on which it is in the rooms will be set apart for the dissection of the perinæum ; and of this opportunity the dissectors of the abdomen must be prepared to avail themselves. A lithotomy staff is to be passed into the bladder, and the hands and feet having been tied together, the subject is to be placed in the same position as for the operation of lithotomy, near the edge of the table. A block is then to be placed below the pelvis, and the scrotum is to be tied up to the handle of the staff. The body may, however, be still more conveniently maintained in the proper position, as is done in some schools, by means of a simple frame with two upright spokes, behind which the limbs are placed while the perinæum is projected forwards between them. A careful incision is to be made in the middle line from the back of the scrotum to the anus, and, being carried round the margin of the anus, is to be prolonged as far as the coccyx ; while a transverse incision is to be directed across the middle line in front of the anus from one ischial tuberosity to the other. Let the dissector reflect the flaps of skin, exposing the external sphincter, and clear out the fat completely from the ischio-rectal fossa of the left side, taking care not to injure the reflection of fascia which bounds it in front in a line with the central point of the perinæum ; and let him study the walls of the fossa (p. 261). On the right side,

enough of fat ought to be left in the ischio-rectal fossa to protect the levator ani and obturator fascia; the inferior hæmorrhoidal vessels and nerve may be dissected towards the border of the sphincter (pp. 426 and 672), and the hæmorrhoidal branch of the 4th sacral nerve may be seen emerging from between the levator ani and coccygeus muscles (p. 668). The two layers of the superficial fascia in the part of the perinæum anterior to the anus are to be distinguished, the most superficial corresponding to what may most correctly be termed the subcutaneous adipose tissue, and being continued over the ischio-rectal fossa, while the deeper layer terminates behind by dipping deeply in front of that fossa. The most superficial layer having been removed, the blowpipe may be introduced beneath the deep layer in the anterior half of the perinæum, so that by inflating the connective tissue underneath it, its external limits, its septum in the middle line, and its continuity forwards may be demonstrated. It may then be slit open, and will be found to be attached to the arch of the pubes externally, to be continuous with the dartos in front, and to be reflected backwards to the triangular ligament behind (p. 259). Underneath it will be found the three long scrotal nerves, viz., the two superficial perineal branches of the pudic and the inferior pudendal branch of the small sciatic nerve, which are to be traced backwards (pp. 670 and 675): also the superficial and transverse perineal arteries are to be dissected out (p. 426). The muscles on which these structures lie are then to be cleaned, viz., the accelerator urinæ embracing the urethra, the erector penis lying upon the crus penis, and the transversalis perinæi (p. 264). In the area between these muscles, subjacent to them, will be observed the triangular ligament or anterior layer of the sub-pubic fascia, and its relations, especially to the urethra, are to be studied (p. 260). It is then to be divided near the bone, and on its deep aspect the deep transversalis muscle, the constrictor urethræ, and the artery of the bulb are to be dissected. The deep transversalis muscle is to be divided, and Cowper's glands are to be sought for in the middle line beneath (p. 963). On the left side are to be traced out the pudic artery and nerve; in doing which the branches of the artery to the bulb and the corpus cavernosum should be observed (pp. 425 and 670). Lastly, a good view of the inferior aspect of the prostate gland may be obtained by dividing the sphincter ani from the accelerator urinæ muscles at the central point of the perinæum (p. 264). In the dissection of the perinæum constant reference should be made to the bearing of its anatomy on the operations of lithotomy (p. 1039). At this period the dissectors may remove one of the testicles for the sake of dissecting it while fresh.

2. *Abdominal wall anteriorly.*—The dissection of the abdominal parietes, in either sex, is to be commenced on the day on which the subject is laid on its back, with a careful examination of the fascia of the inguinal region, on each side, as far as Poupart's ligament. This should, if possible, be undertaken in association with the dissector of the lower limb. An incision is to be made in the middle line from the xiphoid cartilage to the pubes, avoiding the umbilicus, and a transverse one meeting the first, inwards from the anterior superior spine of the ilium. Let the dissector raise the lower of the two flaps of skin thus marked out, remove the subcutaneous layer of fat and fascia, and reflect the deeper layer, usually called superficial fascia, in the same direction as the skin, so as to see the manner in which it is bound down in the line of Poupart's ligament. Let him at the same time observe the superficial epigastric and circumflex iliac arteries and veins, and the continuation of the superficial fascia over the region of the spermatic cord

towards the scrotum in the male, or to the labia in the female (pp. 257 and 437). He will also examine the external abdominal ring, its pillars, the intercolumnar fascia, and the emergence of the spermatic cord in the male, or the round ligament of the uterus in the female (pp. 964 and 986); and he will notice the terminal branches of the ilio-inguinal and ilio-hypogastric nerves (p. 660).

The integument is next to be removed from the upper part of the abdomen, and along with it the subcutaneous fat; only a sufficient thickness of superficial fascia being at first left to preserve the cutaneous nerves. These will be found in two ranges, the one situated near the middle line, and consisting of the anterior branches of the lower intercostal nerves, the other range emerging laterally, and consisting of the lateral cutaneous branches of the same nerves (p. 657). Let the external oblique muscle then be fully dissected, its posterior border being brought, if possible, into view (p. 248). The aponeurosis of the external oblique muscle is next to be divided by an incision carried transversely inwards from the anterior superior spine of the ilium, the inferior part of the aponeurosis being left for future examination; and the dissector will proceed to separate successively the attachments of the muscle to the crest of the ilium and each of the eight lower ribs, and will reflect the muscle towards the middle line as far as it admits of it. The internal oblique muscle, having next been examined, is to be reflected in the same way, and the transversalis muscle exposed and examined (pp. 250, 253).

The deeper parts involved in the descent of inguinal hernia are now to be studied. For this end, the remaining part of the aponeurosis of the external oblique muscle is to be divided along its inner attachment, down to the symphysis pubis; the lower border of the internal oblique muscle is to be examined, and, in the male, the cremasteric muscular fibres which are continuous with it are to be followed down to the testicle. The lower parts of the internal oblique and transversalis muscles are to be successively detached from Poupart's ligament and turned inwards, and their conjoined tendon is to be made evident. The fascia transversalis, with the internal abdominal ring, is now brought into view, and the subperitoneal fat may be seen shining through it (p. 258). The student will observe particularly the structures which lie in contact with the spermatic cord in its course from the internal to the external abdominal ring, and which are described as forming the walls of the inguinal canal (p. 963). He will also raise the fascia transversalis, and note the infundibuliform fascia and the circumflex iliac and epigastric arteries (p. 432); and will acquaint himself with the relations of the latter to the direct and oblique varieties of inguinal hernia, and with the coverings which these herniæ receive in their descent (p. 1029).

Poupart's and Gimbernat's ligaments may now be examined from the deep aspect, and, by separating the subperitoneal fat from the junction line of the fascia transversalis and fascia iliaca, the student will obtain a view of the deep crural arch, the crural ring, and the septum crurale (p. 258)—structures which are to be noted in relation to femoral hernia (p. 1033). He will then open the sheath of the rectus muscle; dissect it and the pyramidalis muscle (p. 253); follow the epigastric artery in the substance of the rectus muscle from below, and the abdominal branch of the internal mammary artery from above; and will, at the same time, examine the deficiency in the lower part of the posterior wall of the sheath of the rectus muscle, and the semilunar folds of Douglas (p. 250).

3. *Male Genital Organs.*—If the subject be a male, the penis ought at

this time to be dissected. On removal of the skin, the dorsal arteries, vein, and nerves, together with the suspensory ligament, will be brought into view (pp. 428, 479, and 671). The corpora cavernosa, corpus spongiosum, and glans are then to be dissected; and the glans may, with care, be separated from the corpora cavernosa (p. 956). The pendulous portion of the penis is to be cut across, the section examined, and the urethra slit open.

The testicles and spermatic cord will next be dissected. The fascia cremasterica is to be laid open, and the cremasteric branch of the epigastric artery and genital branch of the genito-crural nerve found (p. 964). The fascia propria is to be removed, and the elements of the cord examined, viz., the vas deferens and the spermatic artery, veins, and nerves. The testicle may then be removed, the tunica vaginalis opened, and the appearance and relations of the epididymis and vas deferens noticed (p. 967). The caput epididymis, in front of which will be seen the hydatid of Morgagni, is to be raised from the tunica albuginea, and the epididymis and coni vasculosi are to be dissected out. The tunica albuginea must then be divided, and the arrangement of the tubuli seminiferi in the lobules made apparent under water, and the mediastinum exhibited.

4. *Abdominal Cavity; Peritoneum; Small Intestines, and Colon.*—The cavity of the abdomen is to be opened by a vertical and a transverse incision crossing one another on the left side of the umbilicus; but the vertical incision is, in the first instance, to be arrested at the umbilicus, in order that the urachus and the fossæ into which the peritoneum is thrown by the obliterated hypogastric arteries may be examined.

The peritoneal cavity, especially the pelvic part, is to be carefully sponged out and all grumous fluid removed from it, and a piece of cotton soaked with spirit is to be laid in the recto-vesical fossa; on the adoption of these precautions the practicability and comfort of the later parts of the dissection materially depend. The general arrangement of the viscera is first to be examined, including the position and relations of the stomach, spleen, liver, duodenum, jejunum, ileum, cœcum and other parts of the colon, the rectum, and the kidneys (p. 823). The folds of the peritoneum are next to be studied (p. 826). This membrane should be followed transversely and vertically throughout the abdominal cavity, and the line of attachment of the mesentery to the wall of the abdomen should be displayed. The disposition of the foramen of Winslow and the great omentum should then be investigated, and, in order that the interior of the sac of the great omentum may be seen, a transverse cut should be made into it below the arch of vessels which lies along the great curvature of the stomach, and by this means the posterior surface of the stomach and the anterior surface of the pancreas will also be brought into view. When the disposition of the great omentum has been observed, the small or gastro-hepatic omentum, the gastro-splenic omentum, the meso-colon, and the relations of the duodenum to the peritoneum will be easily followed.

After the study of the peritoneum has been completed, the transverse colon is to be lifted upwards, and the small intestines turned over to the left side, in such a manner as to display the whole of the upper or right side of the mesentery; and the distribution of the superior mesenteric artery, from the lower border of the pancreas downwards, with the accompanying vein and plexus of nerves, is then to be brought out by dissection (pp. 410 and 702).

From its right side the artery will be seen to give off the middle colic, right colic, and ileo-colic branches, and from its left side about a dozen

branches to the small intestines; and of these intestinal branches the dissector may trace the primary, secondary and tertiary arches of anastomosis. If the left branch of bifurcation of the middle colic artery be followed, it will lead the dissector to the left colic, and so to the trunk of the inferior mesenteric artery, with its accompanying vein and nerves, situated to the left of the mesentery; and to study these the intestines must now be turned over to the right side. In addition to the left colic, the sigmoid branch of the inferior mesenteric artery will then also be seen, and the first part of the superior hæmorrhoidal vessels before they descend into the pelvis upon the meso-rectum (p. 412).

The dissector will now tie the intestine, a little below the termination of the duodenum, with two ligatures about an inch and a half distant, and will divide it between the ligatures; in like manner he will secure and divide the great intestine at the lower extremity of the sigmoid flexure: he will then remove from the body the whole length of intestine between the upper and lower ligatures. To do this properly, he must begin from above, and pulling the ligatured extremity upwards with his left hand, with his right apply the scalpel lightly to the edge of the mesentery, close to the bowel. By this means the whole small intestines may with ease be removed, and the mesentery left in the abdomen. The large intestine may now also be removed as far as the rectum. The intestines are to be taken to the trough, and there they are to be thoroughly cleaned, by having water run through them from the jejunal end. They may then be spread out on a table and inflated, in order that the relative length and diameter of the different parts may be observed, the arrangement of muscular bands on the colon, and other facts as to their structure (pp. 840 and 854). The small intestine is to be separated from the great, several inches above the cæcum. A portion near the upper end may be cut separate, inflated and dried, in order to show the valvulæ conniventes which are thus put upon the stretch. The remainder is to be slit open in its whole extent, which may be best done with a pair of scissors, one of the points of which has been blunted with a small piece of cork; the appearance of the mucous membrane in the different parts is then to be studied, attention being particularly directed to the distribution of the villi and valvulæ conniventes (p. 842), and to the patches of Peyer's glands (p. 846). The great intestine is next to be divided some inches beyond the cæcal valve, and the remainder is to be slit up and its mucous membrane examined. Lastly, the cæcum is to be very carefully washed, and the structure and action of the cæcal valve studied, by filling the portion of colon with water (p. 852). The water will be retained although the portion of ileum be left untied, and the position of the valve when closed may thus be seen. The cæcum may then be slit open on the side opposite the valve, and the vermiform appendage may also be opened to observe its glandular structure.

5. *Stomach and Duodenum, Pancreas, Spleen, and Liver.*—The duodenum and stomach are to be slightly inflated, and the arteries arising from the cœliac axis are to be dissected (p. 406). The student may begin by dissecting the splenic artery, following its course to the spleen, and observing its branches to the pancreas, to the stomach, the vasa brevia, and the left gastro-epiploic artery. Let him next trace the coronary artery of the stomach along the small curvature of that organ. Then, in following out the hepatic artery to its division into right and left branches, he will find the pyloric branch anastomosing with the coronary artery; the cystic branch going to the gall bladder; and the gastro-duodenal branch dividing

into the right gastro-epiploic which anastomoses with the left gastro-epiploic, and the superior pancreatico-duodenal which anastomoses with the inferior pancreatico-duodenal branch of the superior mesenteric artery.

The inferior mesenteric vein will be traced upwards behind the pancreas to join the splenic vein, which, passing transversely onwards to meet the superior mesenteric vein, will be seen to form with it the trunk of the vena portæ (p. 479). The position of the common bile duct with reference to the hepatic artery and portal vein is to be observed, and the duct is to be traced up into the hepatic and cystic ducts and downwards to the duodenum (p. 867). The relations and structure of the pancreas are then to be examined, and the pancreatic duct is to be traced along its posterior aspect to its termination in the duodenum along with the common bile duct (p. 881). The spleen may now be removed, its blood-vessels dissected, a section made of it, and some of the pulp may be washed away to show the trabecular structure in the interior of the organ (p. 883). The stomach may now be removed along with the duodenum, and a careful examination made of the structure of these organs; the shape of the stomach, its three layers of muscular fibres, and the construction of the pyloric valve being specially noted (p. 830).

The liver is next to be studied. Its ligaments, viz., the falciform ligament, the round ligament or obliterated umbilical vein, the coronary, and the two lateral or triangular ligaments are first to be examined; after which the organ may be removed from the body (p. 865). In doing this, the inferior vena cava must be divided both above and below the liver. The dissectors may now observe the division of the liver into a right and left lobe, as also the quadrate, Spigelian, and caudate lobes: they will likewise note the various fissures, viz., the transverse or portal; the longitudinal or antero-posterior, divided into an anterior part containing the remains of the umbilical vein, and a posterior part in which the remains of the ductus venosus are situated; the fissure or fossa of the gall bladder, and the fissure or fossa of the vena cava (p. 862). They will observe the openings of the hepatic veins into the part of the vena cava imbedded in the posterior border of the liver, and follow the divisions of the hepatic arteries, portal vein and hepatic ducts, as far as possible into the substance of the liver. In doing this the capsule of Glisson sheathing these parts is to be observed: the appearance of the substance of the liver may then be exhibited by minuter dissection; and the gall-bladder having been opened and washed, the structure of its coats and the peculiar reticulated arrangement of its mucous membrane may be examined.

6. *Deep Posterior part of the Abdominal Cavity.*—On returning to the examination of the parts remaining in the abdomen, the dissectors will begin by tracing out the plexuses of the sympathetic nerves. The superior and inferior mesenteric plexuses, in connection with the aortic plexus, are to be traced upwards into the solar plexus, and the nerves proceeding from the aortic plexus downwards into the hypogastric plexus. The solar plexus will be found surrounding the aorta at the root of the cœliac axis; also, its semilunar ganglia, one on each side, and the splanchnic nerves passing through the crura of the diaphragm to terminate in it (p. 699). The dissectors will now follow the plexiform nerves which emanate from the solar plexus and surround the arteries in the neighbourhood; namely, the cœliac plexus subdividing into hepatic, splenic and coronary; also, the supra-renal and renal, and the spermatic plexuses. In doing this the supra-renal capsules will fall under observation, and care is to be taken in the

removal of the surrounding adipose tissue not to injure their substance, which is easily torn (p. 939): after they have been carefully cleaned, these bodies may be examined by incisions into their substance.

The aorta and inferior vena cava are then to be dissected, and also the common and external iliac arteries and veins, together with the kidneys and ureters. The branches of the aorta to be examined are the inferior phrenic, the cœliac axis, the superior mesenteric, the supra-renal, the renal, the spermatic, the inferior mesenteric, the origins of the four pairs of lumbar arteries, and, continuing the direction of the aorta from its point of bifurcation, the middle sacral artery. The two common iliac arteries and veins must at this time be cleaned, also the ureters; and the dissection may be carried down along the external iliac vessels, as far as the origin of the epigastric and circumflex iliac arteries; in doing which the relations of the iliac arteries and veins will be carefully observed (pp. 418, 473, and 477). The position and relations of the kidneys are now to be examined, and more particularly the position of the renal artery, renal vein, and ureter, as they enter the gland (p. 926). The kidneys having been removed from the body, are to be opened by a transverse vertical section, to exhibit the pelvis, calyces, and pyramids, the cortical and internal tubular substances, and the Malpighian glomeruli: the fibrous tunic which invests the kidney is also to be observed. The receptaculum chyli or commencement of the thoracic duct will be found beneath the right crus of the diaphragm (p. 487), as also the commencement of the vena azygos in connection with some of the lumbar veins (p. 469).

7. *Upper and Posterior Wall of the Abdomen.*—The diaphragm is now to be dissected (p. 243). Anteriorly will be found its attachments to the six lower ribs interdigitating with those of the transversalis muscle; posteriorly will be found the two crura and the ligamenta arcuata externa and interna; while the fibres passing from all those parts will be traced to their connection with the central tendon; and the openings for the aorta, œsophagus, and vena cava inferior will be examined. The surface of the psoas magnus muscle is next to be cleaned, as well as that of the psoas parvus lying superficial to it (if it be present) (p. 272); and, emerging from the fibres of the psoas magnus, the genito-crural nerve will be found and followed downwards. The outer nerves of the lumbar plexus will be observed principally on the outer and inner aspects of the psoas muscles (p. 660). The fibres of these muscles are to be dissected away from the nerves of the lumbar plexus. In addition to the communicating branches of the plexus, there will be observed, proceeding from the anterior division of the first lumbar nerve, the ilio-hypogastric and ilio-inguinal nerves, often united into one; from the second lumbar nerve the external cutaneous and genito-crural nerves; from the second, third, and fourth lumbar nerves together, the anterior crural and the obturator nerves; and, lastly, the lumbo-sacral cord, formed by the union of a part of the fourth with the whole of the fifth nerve (p. 658). On the bodies of the vertebræ will be found the lumbar part of the chain of sympathetic ganglia; the branches of communication between which and the spinal nerves are to be dissected (p. 696).

At this time the dissectors ought to revert to the arrangement of the posterior part of the transversalis muscle. This they will find to be continued into an aponeurosis which is connected behind with three layers; of these the most posterior is the fascia lumborum observed in the dissection of the back, the second lies in front of the erector spinæ muscle, and the foremost is a much thinner membrane placed in front of the quadratus

lumborum muscle. The quadratus lumborum and iliacus muscles are now to be dissected (pp. 255 and 271). On removing the iliacus from the iliac fossa, the distribution of the ilio-lumbar artery will be traced, and its anastomoses with the last lumbar and the circumflex iliac artery exhibited (p. 429).

8. *Dissection of the Pelvis.*—The pelvis with several of the lumbar vertebræ ought now to be separated from the rest of the trunk, and before proceeding further, the dissector should carefully remove the superfluous masses of muscle and other soft parts adherent to the outer surface of the bones.

Female Genital Organs.—If the subject is a female, the perinæum is first to be dissected. The exact position of the orifice of the urethra is to be examined with reference to the passing of the catheter (p. 980). The fat is to be removed from between the ischium and rectum; and as this is being done the inferior hæmorrhoidal and superficial perineal vessels and nerve will be brought into view (pp. 426 and 670). The sphincter muscles of the rectum and vagina, the levator ani and transversalis muscles, and the obturator fascia will be seen (p. 265). From among the fat on the fore part are to be dissected out the crura of the clitoris and the erector muscles embracing them; and on the side of the vulva the bulbus vestibuli. The glands of Bartholin are to be sought at the back part of the lower end of the vagina, and the duct of each followed to its orifice by the side of the hymen or carunculæ myrtiformes. Internal to the crus clitoridis the triangular ligament or subpubic fascia will be found extending from the pubic arch to the vagina (pp. 977 and 260).

The bladder ought now to be partially inflated, and the reflections of the peritoneum in the pelvic cavity examined, especially the posterior, lateral, and anterior false ligaments of the bladder, and in the female the broad ligament of the uterus, with the ovary, Fallopian tube, and round ligament (pp. 947 and 985). Let the peritoneum then be reflected from the walls of the pelvis so as to exhibit the lateral and anterior true ligaments of the bladder, and the whole internal aspect of the pelvic fasciæ (p. 260). In order to have a complete view of these fasciæ, it will be necessary to remove a portion of the os innominatum of the right side. This must be done in such a manner as not to interfere with the attachments of the fasciæ: while, therefore, the anterior and lower part of the bone with the acetabulum is to be removed, the brim of the pelvis and the boundary of its outlet are to be preserved, as well as the sacro-sciatic foramina. With a little care, and preliminary observation of the form of the innominate bone, this may be done by means of a single section with the saw, carried close by the brim of the pelvis, and downwards in such a direction as to remove the greater part of the thickness of the ischial tuberosity and pass as near as possible to the sacro-sciatic notches, without breaking into them. By this means the hip-joint may be removed intact; and should it not have been dissected along with the leg, to which it properly belongs, the dissectors of the abdomen will now have an opportunity of examining it; and may especially observe the action of the ligamentum teres, by removing the deep part of the acetabulum, while the capsule of the joint is left intact (p. 151).

Returning to the pelvis, the opening in its lateral wall is to be enlarged, if necessary, with the bone-nippers, and the obturator internus muscle is to be carefully removed, and the peculiar arrangement of its tendon remarked (p. 269). On the inner aspect of that muscle will be found superiorly the undivided pelvic fascia, inferiorly the obturator fascia, and between the two

the white band stretching from the symphysis pubis to the spine of the ischium, which marks the level at which the pelvic fascia splits into the recto-vesical and obturator fasciæ; while in the upper part of the obturator foramen the obturator vessels and nerve will be seen issuing from the interior. If the ischio-rectal fossa be now thoroughly cleaned, a complete view of the layers of fascia will be obtained, and of their relation to the levator ani muscle (p. 260). The brim of the pelvis is next to be sawn through near the symphysis pubis, on the side on which the dissection has been made, and is to be removed. By this means, if the subject be a male, the relations of the fascia to the prostate gland will be better seen. The ureters and the vasa deferentia are to be followed as far as the bladder; the sympathetic nerves of the hypogastric plexus are to be traced in their distribution to the pelvic viscera (p. 702); and the branches of the internal iliac vessels are to be dissected. The internal iliac artery will be found to give off to the walls of the pelvis and to the external parts, the gluteal, ilio-lumbar, and lateral sacral arteries, constituting the branches of its posterior division; the obturator, internal pudic, and sciatic arteries in connection with its anterior division: while to the viscera it supplies the superior vesical with the obliterated hypogastric artery, the inferior vesical giving the middle hæmorrhoidal, and, in the female, the uterine and vaginal arteries (p. 420). The first group may perhaps be best seen on the entire side, and the second and third group on the dissected side of the pelvis. On the former side the sacral nerves are to be displayed (p. 268), and the origin of the pyriformis muscle examined. The junction of the lumbo-sacral cord with the anterior divisions of the three first sacral nerves and a branch of the fourth, to form the sacral plexus, will now be brought into view (p. 669). The gluteal nerve will be found arising from the lumbo-sacral cord (p. 667); and arising from the sacral plexus will be found the great and small sciatic nerves, the pudic nerve, the nerve to the obturator internus muscle, and other muscular branches (p. 670). The remaining branches of the fourth sacral nerve will be found to aid the hypogastric plexus in the supply of nerves to the viscera: at the same time the small fifth sacral and coccygeal nerves may also be dissected (p. 668). The coccygeus and levator ani muscles are to be cleaned on their upper aspects, when they will be seen to form a continuous muscular floor to the pelvic cavity (p. 262). The chains of sympathetic ganglia are then to be dissected in front of the sacrum, and, if possible, the lowest parts traced to their junction in front of the coccyx (p. 696).

9. *Pelvic Viscera.*—It may be proper to examine the muscular walls of the bladder in the inflated condition of the organ, before its removal from the pelvis (p. 944); after which the viscera are to be separated from their attachments to the walls of the pelvis, and removed in one mass.

The rectum may then be carefully dissected away from the rest of the viscera, the extent of its connection with them being at the same time observed (p. 856). Its muscular coats having been sufficiently examined, it is to be slit open and washed, in order that the general appearance and folds of its mucous membrane may be seen. In the male subject the prostate gland enveloped in its fibrous covering, the vesiculæ seminales, and the vasa deferentia are to be carefully dissected (pp. 952 and 971); the bladder is to be opened from before, the neck being left in the first instance entire; and the openings of the ureters and urethra, with the trigone between them, are to be examined (p. 948). The prostatic, membranous, and bulbous parts of the urethra are then to be slit open from above, the varying dia-

meter of the urethra observed, as also in its prostatic part, the verumontanum or caput gallinaginis, the sinus pocularis, and the orifices of the common ejaculatory ducts (p. 961). The junction of the vas deferens and vesicula seminalis to form the common ejaculatory duct is to be displayed; and a longitudinal section of the prostate gland may be made to show its thickness, consistence, and structure: the relations of its base to the neck of the bladder should be particularly observed, with the circle of veins of the vesical plexus in the angle between them.

In the female subject the bladder is to be opened and examined as in the male, and the length and diameter of the urethra observed (p. 980). The vagina is then to be cut open a little on one side of the middle line in front, when the rugæ of its mucous membrane will be seen; also, at its entrance, the carunculæ myrtiformes, and, projecting into it above, the cervix uteri (p. 981). The ovary with its ligament and mesovarium, the Fallopian tube, the round ligament of the uterus, and, between the ovary and Fallopian tube, the tubules termed parovarium or organ of Rosenmüller, are next to be dissected, and the external configuration of the uterus examined (p. 982). The student will then notice the position and appearance of the os uteri externum, and will open the uterus on its anterior aspect by a line of section which, by dividing into two superiorly, is prolonged to both of the cornua (p. 984). He will thus see the size and shape of the triangular cavity of the uterus, the cavity of the cervix, the rugæ of its mucous membrane, and the os uteri internum.

10. *The Pelvic Ligaments.*—At the conclusion, the articulations of the pelvic bones may be examined, if they are still in a condition fit for dissection (p. 147). The symphysis pubis with its concentric laminæ of fibro-cartilage is first to be examined; then the articulation of the pelvis with the fifth lumbar vertebra, especially the sacro-vertebral and ilio-lumbar ligaments: the great and small sacro-sciatic ligaments should be cleaned, and, by removing the remains of the origin of the obturator internus muscle, the obturator membrane.

The anterior and posterior ligaments and the intervertebral disc of the sacro-coccygean articulation are to be observed: lastly, the strong posterior and the thinner anterior sacro-iliac ligaments having been dissected, the last mentioned is to be divided, and the cartilaginous surfaces of the sacro-iliac synchondrosis are to be brought into view by forcing open the articulation.

V.—LOWER LIMBS OR INFERIOR EXTREMITIES.

The right and left limbs constitute each a part, the dissection of which should extend over a period of not less than four weeks. It includes the whole limb below Poupart's ligament and the crest of the ilium, but not the perinæum.

1. *The Gluteal Region.*—The dissection of the gluteal region, the back of the thigh, and the popliteal space is to be completed in the four days during which the subject lies on its face. To remove the integument from the buttock let an incision be carried along the crest of the ilium, brought downwards in the middle line of the sacrum and curved outwards in the fold of the nates, then directed obliquely to the outside of the thigh about five or six inches below the great trochanter. The junior student will at once proceed to clean the gluteus maximus muscle in the direction of its fibres (p. 266). The senior student will examine the arrangement of the

cutaneous nerves in this region. Of these he will find, descending over the crest of the ilium, in order from before backwards, the lateral branches of the last dorsal and ilio-hypogastric nerves (pp. 658 and 660), with several branches of the lumbar nerves (p. 634); and, piercing the gluteus maximus muscle near its posterior attachment, some small cutaneous twigs from the posterior divisions of the upper sacral nerves (p. 635); lastly, turning round its inferior border, branches from the small sciatic nerve (p. 675). It will be observed that the fascia lata, which is strongly developed over that part of the gluteus medius which lies in front of the gluteus maximus muscle, on reaching the upper border of the gluteus maximus, divides into two laminæ, of which one is continued on the superficial, and the other on the deep aspect of that muscle (p. 292). Care is to be taken to lay bare the inferior border of the gluteus maximus in its whole extent; and a synovial bursa over the tuberosity of the ischium is to be sought for. The muscle is then to be divided close to its iliac and sacral attachment, and in turning it forward, the sciatic artery and the superficial branch of the gluteal artery will come into view. The branches of these arteries and of the small sciatic nerve which enter the muscle are to be followed out to some extent, and they may then be divided to permit the complete reflection of the muscle. While this is being done a large synovial bursa will be found between the trochanter major and the insertion of the gluteus maximus into the fascia lata.

The fascia lata is to be removed from the upper part of the gluteus medius muscle, and the parts exposed by the removal of the gluteus maximus are to be cleaned in their order from above downwards, viz.: the back part of the gluteus medius muscle, the gluteal vessels (p. 429), the pyriformis muscle, the sciatic vessels and the great and small sciatic nerves (p. 674), the gemelli muscles, superior and inferior, with the tendon of the obturator internus muscle between them (p. 268). The tendon of this muscle may now be dissected from between the gemelli, divided and turned back, to show the synovial cavity in which it plays upon the smooth trochlear surface of the ischium. The quadratus femoris, the tendon of the obturator externus muscle situated more deeply, the upper part of the adductor magnus muscle, and the origin of the hamstring muscles are then to be exposed. From the small sciatic nerve the inferior pudendal branches will be seen given off, in addition to those already mentioned, and from the sciatic artery, besides muscular branches, the coccygeal branch, the branch to the great sciatic nerve, and that by which it anastomoses with the internal circumflex artery may be traced. On the spine of the ischium also will be seen the pudic vessels and nerve, and the nerve to the obturator internus muscle (pp. 425 and 670); and descending under cover of the tendon of the obturator internus and the gemelli is the small nerve to the quadratus femoris.

The gluteus maximus muscle having been entirely removed from its upper attachment, and the tendon of insertion being left, the gluteus medius is to be raised from the ilium in three-fourths of its extent; its anterior border and that of the gluteus minimus muscle being left for dissection from the front. The attachments of the gluteus medius muscle are to be observed, as also the superior and inferior deep branches of the gluteal artery, and the distribution of the gluteal nerve (pp. 429 and 667). The posterior part of the gluteus minimus may then be raised from the ilium to show the extent of its attachment to that bone, and its relation to the capsule of the hip-joint.

2. *The Popliteal Space.*—It is advisable to dissect this space before the

posterior femoral region. In order to open it the integument may be divided by a longitudinal incision of considerable length, which may be crossed if necessary by a transverse one in the middle of the space, sufficient to allow the integument to be thrown freely back. On removal of the superficial fat, the fascia lata, which is strong in this region, will come into view, and, in the lower part of the space, the terminal twigs of the small sciatic nerve (p. 675), and the upper part of the short saphenous vein (p. 476). The fascia lata is to be divided, and the fat carefully removed from the space, its boundaries cleaned, and the vessels and nerves with their branches traced. Superiorly the biceps muscle on the outside, and the semitendinosus and semimembranosus muscles on the inside, and inferiorly the heads of the gastrocnemius muscle with the small belly of the plantaris will thus be exposed.

Lying in the space the dissector will find the external and internal popliteal nerves giving off their articular and sural branches (pp. 676 and 679), and more deeply the popliteal vessels in a common sheath (p. 441). He will follow out the branches of the popliteal artery, viz., its five articular branches, the superior, azygos, and inferior, and its sural branches. On the surface of the popliteal artery, where it enters the space, may be found a twig of the obturator nerve (p. 663).

When the dissection of the popliteal space has been completed, it is to be united to that of the gluteal region by an incision along the posterior part of the thigh. The course of the small and great sciatic nerves will thus be laid bare, together with the biceps, semitendinosus and semimembranosus muscles, the twigs of the great sciatic nerve supplied to these muscles, and to the adductor magnus, and the four perforating branches of the deep femoral artery (p. 439); the posterior aspect of the adductor magnus muscle will also be exposed.

3. *The Front of the Thigh.*—On the day on which the subject is laid upon its back, the student should begin the dissection of the front of the thigh, by studying the fasciæ connected with the descent of femoral hernia. For this purpose an incision is to be made from the neighbourhood of the anterior superior spinous process of the ilium inwards, in the line of the groin, and carried half away down the inside of the thigh. The large flap of integument thus marked out is to be raised and turned outwards. The subcutaneous fascia is then to be laid bare by the removal of any fat, and it will be advantageous if this can be done in concert with the dissector of the abdomen (p. 292). Various small superficial arteries and veins will be seen, viz.: the superficial epigastric, superficial circumflex iliac, and superior and inferior superficial pudic (p. 437). The fascia lata will be laid bare, and the cribriform fascia overlying the saphenous opening. On the surface of the fascia lata will be brought into view the internal or long saphenous vein passing into the saphenous opening, frequently presenting two branches (p. 475); nearly in front of the femoral artery, the crural branch of the genito-crural nerve; and in front of the anterior superior spine of the ilium, the external cutaneous nerve (p. 660). A twig of the ilio-inguinal nerve may also be seen distributed to the skin of a small part of the thigh close to the pubes. The border of the saphenous opening is to be made distinct by removing the cribriform fascia, and in doing this the attachment of the superior cornu or falciform process to the pubic portion of the fascia lata is to be shown (p. 293). This falciform process is then to be separated from the fascia lata and turned to the outside sufficiently to expose the infundibuliform or crural sheath, investing the femoral vessels, and the dissector

may examine the three compartments into which this sheath is divided, and which contain respectively the artery, the vein, and a lymphatic gland; the latter blocking up the crural aperture between the femoral vein and Gimbernat's ligament, through which femoral hernia descends. All the relations of these parts are to be carefully studied with special reference to the operations for strangulated femoral hernia (p. 1036).

The incision on the inner side of the thigh is now to be prolonged downwards towards the middle line beyond the knee, and the dissection of the front of the thigh continued. The two middle and the two internal cutaneous branches of the anterior crural nerve, together with the branch from the internal saphenous nerve to the integument of the knee, and the internal saphenous vein, will be dissected out, and the fascia lata in front of the thigh made clean (p. 664). The fascia is then to be removed, and the communications of the internal cutaneous, internal saphenous, and obturator nerves sought in the lower part of the inner aspect of the thigh (p. 666). Scarpa's triangle is now to be cleaned, and the dissection of the femoral vessels both in that space and in the after part of their course is to be studied (p. 434). Towards its termination below the middle of the thigh, the femoral artery will be observed to be covered by a tendinous expansion, which conceals it for a part of its course before it pierces the tendon of the adductor magnus muscle: in the passage so formed, known as Hunter's canal, the femoral artery, which is accompanied by the internal saphenous nerve, will be seen to give off the anastomotic branch (p. 293).

The deep femoral artery should be dissected as far as the upper border of the adductor longus muscle; and the origins of its first branches are to be brought into view, viz.: the internal circumflex artery, dividing into ascending, transverse, and descending branches. One or both of the circumflex arteries often arise from the femoral artery immediately above the origin of the deep femoral (p. 438). The sartorius muscle is to be cleaned, and likewise the gracilis muscle, and the surface of the other adductors; the relations of the inferior tendons of the sartorius, gracilis, and semitendinous muscles may also be exposed (pp. 273 and 276). The student will then direct his attention to the outer part of the thigh near the hip. He will there dissect the fascia lata from the remaining part of the gluteus medius muscle, and from the tensor vaginæ femoris muscle, leaving at first a strip of the fascia extending down to the knee on the outside of the leg, and he will afterwards expose the deeper band of the fascia which passes inwards to the hip-joint from within the upper part of the muscle (pp. 273 and 292). He will also find the branch of the gluteal nerve to the tensor vaginæ femoris by dissecting between it and the gluteus medius muscle (p. 667). Let him divide successively the tensor vaginæ femoris and the remains of the gluteus medius and minimus, and dissect the two last muscles down to their inferior attachments, so as to exhibit the bursæ between them and the trochanter major, and the connection of the gluteus minimus with the capsule of the hip-joint (p. 268). While engaged with this proceeding he will be enabled to dissect more particularly the ascending and transverse branches of the external circumflex artery, and to examine their anastomoses with the gluteal artery (p. 438). Let him then clean the rectus muscle, trace its anterior and posterior heads close to their origins, and observe the positions of the limb in which they are respectively tightened (p. 274). The trunk of the anterior crural nerve is now to be cleaned, its branches to the extensor muscles are to be dissected, the internal saphenous nerve laid bare as far as the knee, and the slender twigs to the pectineus muscle seen

passing behind the femoral vessels. These last may be most easily found if the common femoral artery be previously divided (p. 664). If the accessory obturator nerve is present, it will now be seen passing over the brim of the pelvis to the outer border of the pectineus muscle which it partly supplies (p. 666). The pectineus and adductor longus muscles are then to be divided, and their attachments carefully dissected. The continuation of the profunda femoris artery behind the adductor longus is to be cleaned; and its four perforating branches, of which the fourth is the continuation of the artery, will be seen piercing the adductor magnus muscle (p. 439). When the pectineus muscle has been reflected, the accessory obturator nerve may be traced to its communication with the main obturator nerve, to the pectineus muscle, and to the hip-joint. The anterior division of the obturator nerve is to be traced down in front of the adductor brevis muscle, and on division of the pectineus muscle its posterior division to the adductor magnus will come into view. The obturator nerve will be observed to supply all the adductor group of muscles (p. 662). The dissector will now trace the internal circumflex artery; he will find it dividing into two branches, one of which passes inwards in front of the obturator externus and adductor brevis muscles, while the other is directed backwards to anastomose with the sciatic artery, and gives off a branch to the hip-joint which enters it by the notch of the acetabulum (p. 439). The obturator externus muscle is to be cleaned, and the external and internal divisions of the obturator artery are to be laid bare from among its fibres (pp. 269 and 423).

The adductor magnus muscle is then to be cleaned and examined (p. 277); and after it the conjoined insertion of the psoas and iliacus muscles (p. 271); the vastus externus, vastus internus and crureus muscles, together with the deep fibres of the latter, called subcrureus, which are inserted into the synovial membrane of the knee-joint (p. 275).

4. *Hip-joint.*—When this stage of the dissection has been reached, the student may either saw through the femur and leave the hip-joint to a more convenient opportunity, or dissect the joint at this time, and afterwards disarticulate the femur. The latter plan is usually to be preferred. In that case, the attachments of all the muscles which act upon or are related to the hip-joint are to be reviewed, and those which remain uncut are to be severed; the capsular ligament is to be cleaned; its thinness or deficiency on the posterior aspect, and the thick accessory or ilio-femoral ligament, strengthening it in front, are to be noted (p. 151). The relation of the head of the femur to the acetabulum in the various positions of the limb and foot are to be observed. The capsule may then be opened, and the cotyloid, transverse, and round ligaments examined, together with the articular surfaces and synovial membrane: the limb may then be removed from the body.

5. *The Back of the Leg.*—After the separation of the limb from the trunk, and when the divided structures have been cleaned and cut conveniently short, the student will proceed with the dissection of the calf and back of the leg, by directing an incision down the middle of the limb to the heel, and reflecting the skin to each side. He will trace the external and internal saphenous veins as far as the outer and inner ankle (p. 475); accompanying the latter he will find the internal saphenous nerve (p. 666), and along with the former he will find the external saphenous nerve arising from the union of the communicans tibialis and communicans fibularis branches of the internal and external popliteal nerves respectively (p. 677). He will also

find another cutaneous branch of the external popliteal nerve ramifying on the other side of the leg. The gastrocnemius muscle is then to be cleaned, and the nerves and vessels entering it are to be more particularly dissected (p. 283). Its thin and flat tendon is then to be carefully divided at its lower part from that of the soleus, and the muscle is to be turned upwards. The soleus muscle will thus be brought into view, and, resting upon it the plantaris (which however is sometimes absent). Between the soleus muscle and the knee-joint the popliteus muscle will be seen protected by the popliteal aponeurosis, and, crossing it, the lower part of the popliteal vessels and internal popliteal nerve giving off branches to these muscles (pp. 442 and 676). The popliteus muscle is to be preserved to be dissected more particularly with the knee-joint. The plantaris and soleus muscles are to be separated from their superior attachments, and the nature and connexions of the tendo Achillis examined (p. 285); after which the latter may be divided near its insertion. The deep fascia is then to be divided, and the flexor longus digitorum, tibialis posticus, and flexor longus pollicis muscles, lying in this order from within outwards, are to be dissected (pp. 286 and 288). The anterior tibial artery will be seen perforating the interosseous membrane to arrive at the front of the leg, and the posterior tibial artery, venæ comites, and nerve are to be studied, and the branches of the nerve to the popliteus and other three deep muscles followed; while the peroneal artery is to be traced downwards in the fibres of the flexor longus pollicis muscle, and will be observed to give off the anterior peroneal and a communicating branch to the posterior tibial artery (pp. 444 and 677). The relations of the tendons, artery and nerve behind and below the inner ankle are to be particularly noted.

6. *The Sole of the Foot.*—The skin is to be reflected by means of an incision along the middle line of the heel and sole, and a transverse one across the balls of the toes. The plantar cutaneous branch of the posterior tibial nerve is to be traced to its distribution; and on removing the fat from the plantar aponeurosis, an outer and inner set of small nerves and vessels will also be found perforating the latter (p. 296). Below the inner ankle the internal annular ligament is to be cleaned, and the tibialis posticus muscle is to be dissected to its insertion (pp. 288 and 295). The skin is to be divided up the middle of the toes; the sheaths for the flexor tendons are to be exhibited, and the digital arteries and nerves on both sides of each of them are to be traced. The plantar aponeurosis is then to be removed by dissection from the muscles which it covers as much as possible, so as to expose the abductor pollicis, flexor brevis digitorum, and abductor minimi digiti muscles (p. 289). The insertions of the tendons of the flexor brevis digitorum are to be followed by dividing the sheaths on the toes; its posterior attachment is to be divided, and the branch of the internal plantar nerve which supplies it sought. This will bring into view the tendons of the flexor longus digitorum and flexor longus pollicis, the union of which will be noted; the flexor accessorius and the lumbricales muscles will now also be dissected (p. 287). Crossing the flexor accessorius muscle are the external plantar artery and nerve; the artery is to be followed to the deeper part of its course where it forms the plantar arch. The branches of the nerve to the flexor accessorius and abductor minimi digiti are to be found, its distribution to the two outer toes is to be traced, as also the origin of its deep branch (p. 679). The flexor accessorius muscle is to be removed from its broad origin, and the tendons of the flexor longus pollicis and flexor longus digitorum are then to be divided. The internal

plantar artery is to be dissected forwards to the inner side of the great toe ; and the internal plantar nerve, after giving branches to the abductor pollicis, flexor brevis pollicis and two inner lumbricales muscles, will be traced forwards to its distribution on both sides of the three inner toes and one side of the fourth toe (pp. 446 and 677). The deep branch of the external plantar nerve is to be traced to its distribution in the two outer lumbricales, the transversus pedis, adductor pollicis, and all the interossei muscles, save the outermost two, which, together with the flexor minimi digiti, are supplied by the external digital branch. The arch of the external plantar artery will at the same time be traced to the first interosseous space, and its digital and other branches dissected (p. 447). After these parts have been examined, the attachments of the flexor brevis and abductor pollicis, transversus pedis, and flexor brevis minimi digiti muscles are to be fully studied.

7. *The Front of the Leg, and Dorsum of the Foot.*—The remaining integument having been removed from the front of the leg and upper surface of the foot, the dissector will trace the cutaneous veins and nerves in this region. On the inner border of the foot will be found the small terminal twigs of the internal saphenous nerve, and in front of the inner ankle the commencement of the great saphenous vein (pp. 475 and 666) ; while on the foot externally, and passing behind the outer ankle, will be observed the external or posterior saphenous vein and nerve (pp. 476 and 677). On the middle of the leg externally, the musculo-cutaneous nerve will be seen piercing the aponeurosis and becoming superficial, and its distribution is to be traced to the inner side of the great toe and to the adjacent sides of the toes in the three outer interdigital spaces (p. 680) ; while the first interdigital space will be found supplied by a branch continued from the anterior tibial nerve. Immediately above and to the inside of the ankle-joint will be found the upper transverse and the lower oblique parts of the anterior annular ligament or retinaculum binding down the tendons of the extensor muscles (p. 295). These are to be kept, the rest of the aponeurosis being removed : there will thus be exposed in order from within outwards, the tibialis anticus, extensor pollicis, extensor longus digitorum, and peroneus tertius muscles, which are to be dissected to their insertions (p. 279). On the dorsum of the foot the extensor brevis digitorum is also to be dissected ; preserving at the same time the anterior tibial vessels and nerves, and the musculo-cutaneous nerves already mentioned. Arising from the outer aspect of the fibula, the peroneus longus and brevis muscles are then to be cleaned (p. 282) : the latter is to be traced to its insertion, but the course of the tendon of the peroneus longus across the sole of the foot will be more fully seen when the ligaments are dissected. The musculo-cutaneous nerve is to be traced upwards to its origin from the external popliteal or peroneal nerve, and, as it pierces the fibres of the peronei muscles in its course round the fibula, its branches to these muscles will be seen. The anterior tibial nerve is then to be traced beneath the muscles and round the fibula, and downwards on the front of the interosseous membrane, and will be found to supply in the leg the extensor longus digitorum, tibialis anticus, extensor pollicis, and peroneus tertius muscles, and on arriving at the foot, the extensor brevis digitorum (p. 682). The anterior tibial artery will at the same time be dissected, and its branches traced, viz., its recurrent branch passing upwards on the tibia through the origin of the tibialis anticus muscle, to anastomose with the articular branches of the popliteal artery ; its muscular branches, and its external and internal malleolar branches ;

here there will generally be seen the anastomoses between the external malleolar and the anterior peroneal arteries (p. 449). The continuation of the anterior tibial artery as the dorsal artery of the foot is to be traced forwards to its junction with the plantar arch in the first interosseous space, and its tarsal and metatarsal branches are to be examined with the branches supplied by the latter to the three outer interosseous spaces (p. 450). Finally, the interossei muscles are to be dissected and examined in their dorsal end plantar aspects (p. 291).

8. *The Knee Joint, Ankle Joint, and Articulations of the Foot.*—The tendons passing near the knee-joint are, in the first place, to be cleaned; and the anastomoses of blood-vessels upon the knee are to be more particularly examined, viz., the anastomotic branch of the femoral artery, the external and internal superior articular, and external and internal inferior articular branches of the popliteal artery, and the recurrent branch of the anterior tibial artery. The three parts of the insertion of the tendon of the semimembranosus muscle and the posterior ligament are to be exhibited (p. 271): the popliteus muscle is then to be dissected out, and its tendon traced to its origin (p. 285); the tendon of the biceps muscle is also to be dissected to its insertion in connection with the external lateral ligament (p. 270); and at the same time the internal lateral ligament is to be displayed (p. 153). In front the ligamentum patellæ is to be cleaned, and the extension upwards of the synovial sac of the knee-joint carefully examined; the joint may then be opened by cutting into the synovial sac at this place, and reflecting the remains of the quadriceps extensor femoris muscle. Inside will be seen the ligamentum mucosum, the alar ligaments, and the fatty processes of the synovial membrane; the extent of the synovial cavity will be carefully inspected, and with a little dissection the crucial ligaments may then be brought into view. The capsule of the joint ought next to be entirely removed, in order that the form and actions of the lateral and crucial ligaments and the movements of the semilunar cartilages may be better studied. The structure of the latter will be best seen after the femur has been separated from the tibia.

The movements of the ankle-joint ought to be studied in connection with those of the tarsal articulations (p. 158). Its principal ligaments are to be cleaned externally, viz., the external lateral in three distinct parts, the internal lateral, and the transverse or posterior. When the internal examination of this joint has been completed, the superior and inferior tibio-fibular articulations and the interosseous membrane are to be studied. On the dorsum of the foot the numerous short dorsal ligaments of the tarsal and metatarsal bones are to be cleaned. On the sole of the foot the superficial and deep parts of the calcaneo-cuboid ligament, the inserted tendons of the tibialis posticus and peroneus longus muscles, the scaphoido-cuboid, scaphoido-cuneiform, and various other shorter ligaments are to be dissected.

The examination of the remaining joints of the foot may then be completed in the following order: the posterior articulation of the astragalus and calcaneum, bounded in front by the strong interosseous ligament; the articunation of the astragalus, calcaneum, and scaphoid, in which the inferior calcaneo-scaphoid ligament is especially to be observed; the calcaneo-cuboid articulation; the articulation between the cuboid and fourth and fifth metatarsal bones; the articulation between the scaphoid and cuneiform bones, which passes forwards between the latter; the articulation between the two outer cuneiform bones and the second and third metatarsal bones; and the articulation between the internal cuneiform and first metatarsal bone.

The mode of connection of the metatarsal bones with each other is to be observed; the interosseous, dorsal and plantar ligaments of their bases, and the transverse metatarsal ligament of their heads. Lastly, the articulations of the metatarsal bones with the first phalanges, and of the phalanges with each other are to be dissected. In connection with the great toe, the arrangement of the sesamoid bones deserves particular attention.

INDEX.

ABDOMEN (*abdo*, I hide), dissection of, 1069
fasciæ of, 257
lining membrane of, 258
muscles of, 248
regions of, 823
viscera of, 824
position of, 826
Abdominal ring, external, 250, 1019
internal, 258, 1023
Abducent (*ab*, from; *duco*, I lead) nerves, 610
Abduction, 120
Abductor. *See* MUSCLES
Absorbent glands, clxxxvi. *See* GLANDS, LYMPHATIC
system, clxxxii. *See* LYMPHATIC SYSTEM
Absorbents, xlviii. *See* LYMPHATICS
Accelerator. *See* MUSCLES
Acervulus (dim. of *acervus*, a heap) cerebri, 552
Acetabulum (a vessel for holding vinegar), 93, 96
Acinus, ccxxiv
Acoustic (ἀκουω, I hear) nerve. *See* NERVE
Acromion (ἀκρον, a summit; ὠμος, a shoulder), 76, 89
Adduction, 120
Adductor. *See* MUSCLES
Adenoid (ἀδην, a gland; εἰδος, form) tissue, lxxix
Adipose (*adeps*, fat) tissue, lxv. *See* FAT
Adventitia capillaris, clxxix
Afferent lymphatic vessels, clxxxvi
nerves, cxxxii, clxii
Affinity, vital, viii
Agminated (*agmen*, a troop) glands, ccxxiv, 846
Air-cells, 899
capillaries of, 902
development of, 904
tubes, 898
Ala pontis Varolii, 517
Ala vespertilionis, 986
Alæ of diaphragm, 245
Alæ—*continued*.
nasi, 771
of sphenoid bone, 40
of vomer, 48
Alar (*ala*, a wing) ligaments, 157
Albinos, pigment wanting in, lxiv
Albumen, vi
of blood, xxxix
Albuminoid principles, chief characters of, vi
Alimentary (*alimentum*, food) canal, 779
Allantois (ἀλλας, a sausage; εἰδος, shape), 995
Alveoli (*alveolus*, a small hollow vessel)
of lower jaw, 51
upper jaw, 44
formation of, 792
of lungs, 900
lymphatic glands, clxxxvii
mucous membrane, cc
stomach, 835
Amphiarthrosis (ἀμφι, on both sides; ἀρθρον, a joint), 119
Ampullæ (*ampulla*, a flask or bottle) of labyrinth, 754
membranous, 758
of Fallopian tube, 992
Amygdalæ (ἀμυγδαλη, an almond), 813
of cerebellum, 554, 577
Amyloid (ἀμυλον, starch; εἰδος, form) bodies in pineal gland, 552
Anapophysis (ἀνα, upwards; *apophysis*), 22
Anastomosis (ἀνα, through; στομα, a mouth) of arteries, clxvii
of veins, clxxiii
Anatomy (ἀνα, apart; τεμνω, I cut) comparative, 1
demonstrative, 1
descriptive, ii, 1
general, ii
systematic, ii, 1
topographic, 1
vegetable, 1
Anconeus (ἀγκων, the elbow), 212
Aneurism, axillary, operation for, 1007
popliteal, operation for, 1015, 1017

Anfractuosities (*anfractus*, a winding), 531
Angeiology (ἀγγειον, a vessel; λογος, discourse), 297
Angle, facial, 73
Angular movement, 120
 processes of frontal bone, 34
Ankle-joint, bones of, 104, 105
 dissection of, 1085
 ligaments of, 159
  annular, 295
 movements of, 160
Annular (*annulus*, a ring) ligament of ankle, 295
  of arm, 138
  of wrist, 144
 protuberance. *See* Pons Varolii.
Annulus ovalis (oval ring), 309
Ansa (a loop) hypoglossi, 626, 640
Ansæ Vieussenii, 693
Antihelix (ἀντι, opposite; *helix*), 741
 fossa of, 741
Antiprostatic (ἀντι, opposite; *prostate*) gland, 963
Antitragus (ἀντι, opposite; *tragus*), 741
Antrum (a cavern), lxxxviii
 of Highmore, 46, 64
 of pylorus, 831
Anus, muscles of, 262, 263, 859
Aorta (ἀειρω, I take up or carry), 332
 abdominal, 404
  branches of, parietal, 416
   visceral, 406
  anastomoses of visceral and parietal branches of, 417
  dissection of, 1075
 arch of, 332
  branches of, 336, 338
  peculiarities of, 336
 bifurcation of, 404
 development of, 325
 foramen in diaphragm for, 246
 orifice of, 313, 315
 sinus of, 335
 thoracic, 401
  dissection of, 1068
 valves of, 307
Aponeurosis (ἀπο, from; νευρον, a string, a tendon), lxxiv, 168
 of diaphragm, 245
 epicranial, 169
 of external oblique muscle, 249
  infraspinatus muscle, 210
  internal oblique muscle, 250
  lower limb, 292
 lumbar, 540
 of transversalis muscle, 253
  upper limb, 230
 vertebral, 240
Apophysis (ἀπο, from; φυω, I grow), lxxxviii
Apparatus ligamentosus, 128
 lachrymal, 709
Appendages, auricular, 304, 308, 311, 315
Appendices epiploicæ, 830
Appendix cæci, 852
 vermiformis, 852
 vesicæ, 951
Aqueduct (*aquæductus*, a conduit) of cochlea, 38, 757
 Fallopius, 38
 Sylvius, 525, 550
 vestibule, 38, 754
Aqueous humour, 737
Arachnoid (ἀραχνη, a spider, or spider's web; εἰδος, shape) membrane, 562, 565
Arbor vitæ (from resemblance of the shrub so called) of cerebellum, 526
 uterinus, 984
Arch of aorta, 332. *See* Aorta
 carpal, posterior, 391
 of colon, 854
 crural or femoral, 1031
  deep, 258, 1033
 palmar, superficial, 393
  deep, 400
 plantar, 447
 pubic, 97
 of a vertebra, 4
 zygomatic, 57
Arches, branchial, 64
 dental, 780
 vascular, in embryo, 325
 visceral, 64
Arciform (*arcus*, a bow; *forma*, shape) fibres, 517
Arcus dorsalis humeri posticus, 385
 superficialis volæ, 393
Areola (a little space) of the mamma, 1002
Areolar tissue, lxix
 corpuscles of, lxxiii
 development of, lxxx
 structure of, lxx
Arm, aponeurosis of, 230
 arteries of, 381
 bones of, 78
 dissection of, 1063
 fascia of, 229
 lymphatics of, 497
 muscles of, 212
  action of, 228
 nerves of, 646—655, 683
 veins of, 465
Arteria anastomotica magna, 440
 centralis retinæ, 729
 collateralis magna, 383
  ulnaris prima, 384
   secunda, 385
 comes nervi ischiadici, 429
 comes nervi phrenici, 374
 dorsalis pedis, 450
 dorsalis scapulæ, 380
 hypogastrica, 420
 maxillaris externa, 349
 pancreatica magna, 409
 pelvica, 420
 princeps pollicis, 399
 profunda femoris, 437

ARTERY—*continued.*
profunda penis, 428, 958
thoracica humeraria, 379
suprema, 379
thyroidea ima, 337, 340
ARTERIES (ἀρτηρια, from ἀρτηρ, that by which anything is suspended; originally applied to the windpipe, by which the lungs might be said to be suspended, τραχεια ἀρτηρια, *arteria aspera*, afterwards to the arteries, at one time supposed, like the windpipe, to contain air. Another less probable derivation is from ἀηρ, air; τηρεω, I keep), General Anatomy of, clxvii
anastomoses of, clxvii
coats, clxviii
contractility of, clxxi
distribution of, clxvii
epithelium of, clxix
muscular tissue of, clxx
nerves of, clxxi
physical properties of, clxviii
rete mirabile of, clxviii
sheath of, clxviii
structure of, clxviii
terminations of, clxxx
tortuosity of, clxviii
vessels of, clxxi
vital properties of, clxxi
ARTERIES, Descriptive Anatomy of, 297
ARTERIES or ARTERY, aberrant, in arm, 385, 387
accessory pudic, 428
of acoustic nerve, 370
acromial thoracic, 379
alveolar, 356
anastomotic, of arm, 385, 388
of thigh, 440
angular, of face, 350
articular, of hip, 439
of knee, 442
auditory, internal, 767
auricular, anterior, 354, 743
posterior, 353, 743
axillary, 377
dissection of, 1062
peculiarities of, 381
basilar, 363, 370
brachial, 381
dissection of, 1064
peculiarities of, 385
surgical anatomy of, 1010
brachio-cephalic, 336, 340
peculiarities of, 337, 340
bronchial, 402, 903
buccal, 356
of bulb, 427
relation of to lithotomy, 1046
capsular, 413
of eye, 733
of liver, 873
cardiac, 338
carotid, common, 336, 341
ARTERY—*continued.*
carotid, common, development of, 327
dissection of, 1053
peculiarities of, 337, 345
surgical anatomy of, 1005
external, 345
peculiarities of, 346
internal, 359
peculiarities of, 360
carpal, anterior radial, 397
ulnar, 391
posterior radial, 398
ulnar, 391
central, of retina, 360, 729, 739
cerebellar, anterior inferior, 370
posterior inferior, 369
superior, 370
cerebral, anterior, 363
middle, 363
posterior, 370
cervical, ascending, 371
deep, 376
of occipital, 351
superficial, 373
transverse, 366, 373
choroid, 363
posterior, 370
of eye, 721
ciliary, 360, 721, 723
circumflex, of arm, anterior, 381
posterior, 380
iliac, 433
superficial, 437
of thigh, external, 438
internal, 439
clavicular, 379
of clitoris, 428
coccygeal, 429
cochlear, 767
cœliac, 406, 837
colic, left, 412
middle, 410
right, 410
communicating, of brain, anterior, 363
posterior, 363, 370
of palm, 393
coronary of heart, 321, 338
peculiarities of, 340
left, 339
right, 339
of lips, 350
of stomach, 407
of corpus cavernosum, 428, 958
cranial, 351
cremasteric, 433
crico-thyroid, 348
cystic, 408
deferent, 421
dental, 356
digital, of foot, 448, 451
of hand, 393
dorsal, of foot, 450
of fore-finger, 398
of great toe, 451
of lumbar, 417

ARTERY—*continued.*
dorsal, of penis, 428
of scapula, 380
of thumb, 398
of tongue, 348
emulgent, 414
epigastric, 432
peculiarities of, 434
relation to femoral hernia, 1034
to inguinal hernia, 1023, 1025, 1030
superficial, 437
superior, 375
ethmoidal, 362
facial, 349
femoral, 434
dissection of, 1080
peculiarities of, 441
relation to femoral hernia, 1033
surgical anatomy of, 1015
deep, 437
dissection of, 1080
frontal, 362
gastric, short, 409
gastro-duodenal, 408
gastro-epiploic, left, 410
right, 408
gluteal, 429
hæmorrhoidal, external or inferior, 426, 858
middle, 421, 858
superior, 412, 858
of hand, peculiarities in, 400
helicine, 958
hepatic, 408, 867, 873
humeral, of acromio-thoracic, 379
transverse, 371
hyoid (lingual), 348
(thyroid), 346
hypogastric, 328, 420
ileo-colic, 410
iliac, common, 418
surgical anatomy of, 1012
external, 431
peculiarities of, 434
surgical anatomy of, 1014
internal, 420
in fœtus, 420
surgical anatomy of, 1014
ilio-lumbar, 429
of index finger, radial, 399
infra-orbital, 357
infra-spinous, 373
innominate, 336, 346
peculiarities of, 337, 340
intercostal, aortic, 402
anterior, 374
superior, 366, 376
interlobular, of liver, 873
interosseous, of arm, 390
anterior, 390
posterior, 391
of foot, 450
of hand, dorsal, 391, 399
palmar, 400

ARTERY—*continued.*
labial, inferior, 350
lachrymal, 357, 360
laryngeal, of inferior thyroid, 371
of superior thyroid, 348
lingual, 348, 812
lumbar, 417
malar, 360
malleolar, external, 450
internal, 449
mammary, external, 379
internal, 366, 374
masseteric, 356
mastoid, 351
maxillary, internal, 354
dissection of, 1055
peculiarities of, 357
superior, 356
median, 391
peculiarities of, 393
anterior, 369
mediastinal, 374
posterior, 402
meningeal, middle and great, 356, 357
of occipital, 351
posterior, 369
small, 356
mesenteric, inferior, 412
superior, 410, 849
metacarpal, 398
of little finger, 391
metatarsal, 450
musculo-phrenic, 375
mylo-hyoid, 356
nasal, of internal maxillary, 357
lateral, 350
of ophthalmic, 362
of septum, 357
nutrient, of femur, 439
of fibula, 445
hip, 429
humerus, 385
radius, 391
tibia, 444
ulna, 391
obturator, 423
peculiarities of, 424
relation to femoral hernia, 1036
occipital, 351
œsophageal, 402
of coronary artery, 407
of inferior thyroid, 371
ophthalmic, 360
ovarian, 414, 416, 987, 992
palatine, inferior or ascending, 349
superior or descending, 357
of pharyngeal, 358
palmar, superficial, 393
deep, 400
palpebral, 362
pancreatic, 409
pancreatico-duodenal, 408
inferior, 410
perforating, of foot, 448

Artery—*continued.*
perforating, of hand, 400
of thigh, 439
of thorax, 374
pericardiac, 374, 402
perineal, superficial, 426
in females, 428
transverse, 427
peroneal, 444
anterior, 445
petrosal, 752
pharyngeal, ascending, 357
phrenic, inferior, 416
superior, 374
plantar, external, 447
internal, 446
popliteal, 441
dissection of, 1080, 1083
profunda, of arm, inferior, 384
superior, 383
of penis, 428
of thigh, 437
pterygoid, 356
pterygo-palatine, 357
pubic, 434
of obturator, 424
pudic, 425
accessory, 428
external, 437
in female, 428
pulmonary, 331, 898, 902, 903
from abdominal aorta, 406
development of, 326
in fœtus, 328
valves of, 307
pyloric, 408
radial, 394
dissection of, 1065
peculiarities of, 385, 386, 399
of index finger, 399
ranine, 349
recurrent, of deep palmar arch, 400
interosseous posterior, 391
radial, 397
tibial, 449
ulnar, 389
renal, 414, 935
sacral, middle, 418
lateral, 430
scapular, posterior, 367, 373
sciatic, 429
sigmoid, 512
spermatic, 414, 975
spheno-palatine, 357
spinal, anterior, 369
of intercostals, 404
of inferior thyroid, 371
of lumbar, 417
posterior, 369
of vertebral, 368
splenic, 408, 886
sternal, 374
sterno-mastoid, 351
stylo-mastoid, 353, 752, 768
subclavian, 364

Artery—*continued.*
subclavian, development of, 327
dissection of, 1053
peculiarities of, 337, 367
surgical anatomy of, 1007
sublingual, 348, 349, 818
of submaxillary gland, 817
submental, 350, 351, 818
subscapular, 379
of suprascapular, 373
supra-acromial, 373
supra-orbital, 360
suprarenal, 413
suprascapular, 366, 371
sural, 442
tarsal, 450
temporal, 353
anterior, 354
deep, 356
middle, 354
posterior, 354
thoracic, acromial, 379
alar, 379
external, 379
long, 379
superior, 379
of thumb, dorsal, 398
large, 399
thymic, 374
thyroid, inferior, 366, 371, 919, 922
lowest, 340, 922
superior, 346, 919, 922
tibial, anterior, 448
dissection of, 1083, 1084
peculiarities of, 451
posterior, 444
dissection of, 1083
peculiarities of, 445
tonsillar, 350, 351, 814
tracheal, 371
transverse, of basilar, 370
cervical, 373
of face, 354
humeral or scapular, 371
of perinæum, 427
tympanic, 356, 752
ulnar, 388
dissection of, 1065
peculiarities of, 385, 386, 391
umbilical, 328, 421
uterine, 422, 987
vaginal, 422
of liver, 873
of vas deferens, 421
vertebral, 366, 367
development of, 327
peculiarities of, 369
vesical, inferior, 421
superior, 421
vesico-prostatic, 421
vestibular, 767
Vidian, 357
volar, superficial, 397.
Arthrodia (ἄρθρον, a joint), 120

Arthrology (ἄρθρον, a joint; λογος, a discourse), 118
Articular (*articulus*, diminutive of *artus*, a joint) arteries. *See* ARTERY
ARTICULATION (*articulus*, a joint), 118
acromio-clavicular, 134, 1064
of ankle-joint, 159, 1085
astragalo-calcaneal, 160
scaphoid, 161
of atlas and axis, 125
calcaneo-cuboid, 162
scaphoid, 161
carpal, 142, 1066
carpo-metacarpal, 144
classification of, 119
coccygeal, 147
costo-clavicular, 134
costo-sternal, 130
costo-vertebral, 128, 1069
costo-transverse, 129, 1069
crico-arytenoid, 910
crico-thyroid, 909
of elbow, 140, 1066
epiglottis, 908
foot, 160, 1085
forearm, 138
hand, 142, 1066
hip, 151, 1082
knee, 153, 1085
larynx, 909
leg, 158
lower limb, 151
metacarpal, 144
metacarpo-phalangeal, 145
metatarsal, 165
metatarso-phalangeal, 166
modes of, 118
movements of, 120
of pelvis, 147, 1078
peroneo-tibial, 158
pubic, 149, 1078
radio-carpal, 142
ulnar, superior, 138, 1066
inferior, 139, 1066
of ribs, 128, 1069
sacro-coccygeal, 1078
iliac, 147, 1078
sacro-vertebral, 147, 1078
scapulo-clavicular, 134, 1064
scapulo-humeral, 136
sterno-clavicular, 134
tarsal, 161
tarso-metatarsal, 164
temporo-maxillary, 132
thyro-hyoid, 909
of tympanic bones, 749
upper limb, 134, 1064, 1066
vertebral column, 121, 1059, 1069
Arytenoid (ἀρυταινα, a pitcher or ladle; εἶδος, shape) cartilages of the larynx, 907
ligaments, 909
muscles, 917
Asternal (ἀ, neg.; στερνον, the breast) ribs, 24
Astragalus (ἀστραγαλος, the ankle-bone, or a dice, the astragali of the sheep having been used as dice by the ancients), 107
Atlas (ἀ euphonic; τλημι, I bear), 8
ligaments of, 125
loop of the, 636
ossification of, 19
Atrium (a court before a house) of auricles of heart, 304
Attollens (*attollo*, I raise up). *See* MUSCLES
Attrahens (*ad*, to; *traho*, I draw). *See* MUSCLES
Auditory artery, 767
canal, external, 743
meatus, external, 37, 61, 743
internal, 38
nerve, 587, 589, 615
arrangement of membranes of, cxlix
cochlear division, 763
vestibular division, 758
process, 37
Auricle (*auricula*, the outer ear) of ear, 740
ligaments of, 742
muscles of, 742
nerves of, 743
vessels of, 743
Auricles of heart, 304. *See* HEART
Auricular arteries, 353, 354, 753
muscles, 170, 742
nerves. *See* NERVES
surface of sacrum, 11, 95
Auriculo-temporal nerve, 606
Auriculo-ventricular furrow, 303
orifices, 308, 312
size of, 322
rings, 316
valves, 305
Axial fibre of nerve. *See* Axis, Cylinder
Axilla, dissection of, 1061
position of parts in, 377
Axis (vertebra), 9
development of, 19
ligaments of, 125
cerebro-spinal, cxxxii, 501
cœliac, 406
cylinder of nerve-fibre, cxxxvi
of pelvis, 99
thoracic, 381
thyroid, 371
Azotised (*azote*, nitrogen) substances, v
Azygos (ἄζυγος, unyoked) artery, 443
veins, 469, 471
uvulæ muscle, 190

BACK, dissection of, 1060
muscles of, 232
Band, furrowed, 525
primitive, of nerve-fibre, cxxxvi
Bands of Goll, 510

Bartholin's glands, 978
Base, molecular, of chyle, xlix
Basement membrane of glands, ccxxiv
of mucous membrane, cxcvii
of skin, cciii
of teeth, 797
Basilar (*basis*, a base) artery, 370
bone, 29
process of occipital bone, 31
Basilic vein (βασιλικος, royal; this vein having been supposed by the old physicians to be connected with the liver and spleen, which they termed the basilic viscera), 466
Basio-glossus (βασις, a base; γλωσσα, a tongue) muscle, 186
Bauhin, valve of, 852
Bellini, ducts of, 930
Bertin, bones of, 40
Biceps (*bis*, twice; *caput*, a head) muscles, 212, 270
Bichat, canal of, 548
Bicuspid (*bis*, twice; *cuspis*, the point of a weapon) teeth, 782
valve, 313
Bile, 879
Bile-duct, common, 868
ducts, aberrant, 877
origin of, 875
structure of, 877
Bipolar nerve-cells, cxl
Biventer (*bis*, twice; *venter*, a belly) muscle, 237
Biventral lobe of cerebellum, 524
Bladder, gall. *See* GALL-BLADDER
BLADDER, urinary, 944
capacity of, 945
coats of, 948, 951
detrusor muscle of, 949
development of, 995
female, peculiarities of, 947
ligaments of, false, 945, 947
true, 260, 261, 945, 952
neck or cervix of, 945, 947
openings of ureters into, 948
position of, 825, 944, 945, 1041
puncture of, 1042
sacculated and fasciculated, 951
sphincter muscle of, 949
structure of, 948
trigone of, 948
urethral orifice of, 948
uvula of, 948
vessels and nerves of, 951
Blastema (βλαστανω, I germinate), xix
Blastoderm (βλαστανω, I bud or germinate; δερμα, a skin), 15
BLOOD, xxvii
arterial and venous, xlii
chemical composition of, xxxiii, xli
circulation of, clxvi
in fœtus, 328
coagulation of, xliv
colouring principles of, xxxiv
BLOOD—*continued.*
corpuscles, pale, xxxi
red, xxviii
differences of, in animals, xxviii
formation of, l
composition of, xxxiii
structure of, xxix
crystals of, xxxv
hepatic, xliii
liquor of, xxxvii
occasional constituents of, xxxii
physical properties of, xxvii
plasma of, xxxii
portal, xliii
renal, xliv
splenic, xliii
tables of composition of, xlii
BLOOD-VESSELS, General Anatomy of, cxlv
development of, clxxx
See ARTERIES, VEINS, CAPILLARIES, also under the several organs and tissues, for blood-vessels belonging to them.
Blumenbach's norma verticalis, 73
BONE, General Anatomy of, lxxxvii
cavities of, lxxxviii
chemical composition of, lxxxix
classes of, lxxxvii
compact or cancellated, xc
corpuscles of, xliv
eminences of, xxxviii
external configuration of, lxxxvii
formation and growth of, cii
Haversian canals, xci
spaces, xciii
lacunæ of, xciv
lamellæ of, xc, xcii, xcv
fibres of, xcv
lymphatics of, cii
madder, influence of, on, cxiii
marrow of, c
nerves of, cii
perforating fibres of, xcvi
periosteum of, c
physical properties of, lxxxviii
processes of, lxxxviii
structure of, xc
vessels of, ci
BONES, Descriptive Anatomy of, 2
of ankle, 107
astragalus, 107
atlas, 8
axis, 9
of Bertin, 40
calcaneum, or os calcis, 107
carpal, 83, 90
clavicle, 77, 89
coccyx, 12
cuboid, 108
cuneiform, of carpus, 84
tarsus, 109
of ear, 748
ethmoid, 42, 69
femur, 100, 111

BONES—*continued.*
fibula, 105, 111
of fingers, 87
of foot, 106
frontal, 33, 67
of hand, 83
humerus, 78, 90
hyoid, 52, 70
ilium, 94, 110
incus, 748
innominate, 93, 110
ischium, 96, 110
lachrymal, 50, 70
lenticular, 749
lingual, 52
of lower limb, 100
lunate, 84
magnum, 85
malar, 49, 70
malleus, 748
maxillary, superior, 44, 69
inferior, 51, 70
metacarpal, 86
metatarsal, 109, 111
nasal, 49, 70
navicular, of carpus, 84
tarsus, 108
number of, 2
occipital, 29, 67
orbicular, 749
palate, 46
parietal, 32, 67
patella, 103
pelvic, 93, 111
phalangeal, of hand, 87, 90
foot, 110, 111
pisiform, 85
pubic, 95, 110
pyramidal, 84
radius, 80, 90
ribs, 24
peculiarities of some, 26
sacrum, 11
scaphoid, of carpus, 84
tarsus, 108
scapula, 74, 89
semilunar, 84
sesamoid, in hand, 88
in foot, 110
of skull, 29
spongy, ethmoidal, 43, 63
inferior, 50, 63, 70
middle, 43
sphenoid, 38, 68
sphenoidal, 40, 69
stapes, 749
sternum, 23
tarsal, 106
temporal, 35
tibia, 103
trapezium, 85
trapezoid, 85
triquetral, 55
turbinate, superior, 43
inferior, 50

BONES—*continued.*
ulna, 81
of upper limb, 74
unciform, 86
ungual, 50
vertebra dentata, 9
prominens, 8
vertebræ, 3
vomer, 48
Wormian, 55
Bourrelet (a cushion or pad), 542
Brachia (arms), in cerebrum, 552, 557
Brachial artery, 381. *See* ARTERY
Brachio-cephalic (*brachium*, the arm; κεφαλη, the head) artery, 336
Brachycephalic (βραχυς, short; κεφαλη, the head) skulls, 73
BRAIN, 513, 529. *See* CEREBRUM and ENCEPHALON.
dissection of, 1049
vessels of, 567
Branchial (βραγχια, gills) arches, 64
clefts, 64
Breast. *See* MAMMARY GLAND.
Bronchi (βρογχος, the windpipe), 889
position of, at root of lungs, 898
vessels and nerves of, 892
Bronchia (βρογχος, the windpipe), 898
development of, 904
Bruch, membrane of, 717
Brunner's glands, 849
Bubonocele (βουβων, the groin; κηλη, a tumour), 1025
Buccal (*bucca*, the mouth) artery, 356
nerve, 606
Buccinator (*buccina*, a trumpet), muscle, 176
Buffy coat of blood, xxxiii
Bulb, olfactory, 584
of urethra, 958
artery of, 427, 1046
Bulbi vestibuli, 975
Bulbo-cavernosus muscle, 264
Bulbs of corpora cavernosa, 956
of fornix, 537
Bulbus arteriosus, 323, 325
Bursa (a pouch), cxciv
Bursæ, synovial, or bursæ mucosæ, cxciv

CADAVERIC rigidity, cxxxi
Cæcum (*i.e.*, *intestinum cæcum*, the blind gut), 852
development of, 861
Calamus scriptorius (a writing pen), 517
Calcaneo-cuboid articulation, 162
Calcaneo-fibular ligament, 160
Calcaneo-scaphoid ligaments, 161
Calcaneo-talar (*calcaneum; talus*, the astragalus) ligament, 160
Calcaneum (belonging to the heel, from *calx*, the heel), 107
Calcar avis (a bird's spur), 544

Calcarine fissure, 536
Calcification of teeth, 797
Calyces (καλυξ, a cup) of kidney, 928
Calvarium or Calvaria (the roof of the skull; *calvus*, bare), removal of, 1049
Camper's facial angle, 73
Canal, alimentary, 779
abdominal portion, 823
development of, 859
auditory, external, 743
internal, 38
of Bichat, 549
carotid, 37, 59
central of modiolus, 756
crural, 293, 1034
dental, 52
facial, 38
femoral, 293, 1034
of Huguier, 745
Hunter's, 294
incisor, 63
infra-orbital, 57
inguinal, 963, 1023
lachrymal, 46, 709
of Nuck, 965, 987
palatine, anterior, 45
posterior, 47, 58
of Petit, 736
pterygoid, 42
pterygo-palatine, 41, 58
sacral, 12
of Schlemm, 721
of spinal cord, 508
spiral, of cochlea, 755
vertebral, 5
membranes in, 563, 564, 565
Vidian, 42, 57
of Wirsung, 882
Canaliculi in bone, xciv
lachrymal, 709
Canalis centralis modioli, 756
membranacea of cochlea, 761
reuniens of cochlea, 761
spiralis modioli, 756, 763
Canals of Gärtner, 998
of Havers, xci
portal, 873
perivascular, cxxxvii
semicircular, of ear, 754
membranous, 758
Cancelli (lattice-work) of bone, xc
Canine fossa, 45
teeth, 781
development of, 800, 803
Canthus (κανθος, the corner of the eye), 705
Capacity of auricles and ventricles, 322
vital, of lungs, 896
CAPILLARY (*capillus*, a hair) vessels, General Anatomy of, clxv, clxxv
development of, clxxx
discovery of, clxxv
network of, clxxv
CAPILLARY vessels—*continued.*
network of, peculiarities of, clxxvi
structure of, clxxvi
vital properties of, clxxix
Capitellum (dim. of *caput*, a head), lxxxviii
of humerus, 79
Capitulum (dim. of *caput*, a head), lxxxviii
of rib, 25
Capsulæ atrabiliariæ, 939
Capsular artery. *See* ARTERY
ligament. *See* LIGAMENT
Capsule, Glisson's, 867, 870
of lens, 733
Capsules, suprarenal, 939
synovial, cxciii
Caput (a head) of bone, lxxxviii
Caput cæcum coli, 825, 852
gallinaginis (woodcock's head), 961
Cardiac (καρδια, the heart) artery, 338
nerves. *See* NERVES
orifice of stomach, 831
Cardinal veins, 484
Carotid (καρωτιδες ἀρτηριαι, soporific arteries, from καροω, I cause sleep: also said to be from καρα, the head; οὐς, the ear) artery. *See* ARTERY, Carotid
canal, 37, 59
foramen, 37
plexus, 689
Carpal (καρπος, the wrist) arteries. *See* ARTERY
ligament. *See* LIGAMENT
Carpo-metacarpal articulation, 144
Carpus (καρπος, the wrist), articulations of, 142
bones of, 83
ligaments of, 144, 231
ossification of, 90, 93
compared with tarsus, 115
CARTILAGE (*cartilago*, gristle), general anatomy of, lxxx
articular, lxxxii
chemical composition of, lxxxiv
cricoid, 906
of ear, 741, 744
ensiform, 23
of epiglottis, 908
fibro-, lxxxvi
interarticular, lxxxvi
hyaline, lxxxi
development of, lxxxv
of ribs, lxxxiii
Meckel's, 66, 769
of primordial cranium, 65
of septum of nose, 772
temporary, lxxxi
thyroid, 906
varieties of, lxxxi
xiphoid, 23
yellow, lxxxv
CARTILAGES, arytenoid, 907

CARTILAGES—*continued.*
of bronchi, 892
of bronchia, 899
costal, 26
connection of ribs with, 130
cuneiform, 908
of larynx, 905
ossification of, 920
structure of, 908
of nose, 771, 772
of ribs, 26
semilunar, of knee, 155
tarsal, of eyelids, 706
of Santorini, 908
of trachea, 890
of Wrisberg, 908
Cartilagines alarum nasi, 772
laterales nasi, 771
minores nasi, 772
sesamoideæ, 772
Cartilago triticea (wheat-shaped cartilage), 909
Caruncula (dim. from *caro*, flesh) lachrymalis, 705
Carunculæ myrtiformes, 978
Casein (*caseus*, cheese), v
Cauda equina (horse's tail), 503, 631
development of, 574
Cavernous nerves of penis, 703
plexus, 689, 690
sinus, 463
tissue, clxxx
Cavities of bones, lxxxviii
of reserve (teeth), 801
posterior, 802
sigmoid, of ulna, 82
Cavity, abdominal, 823
buccal, 779
cotyloid, 96
cranial, 60
cranio-vertebral, development of, 573
glenoid, 76
neural, 3
pulp, of tooth, 785
semilunar of radius, 81
visceral, 3
CELLS, anastomosing, of cornea, 715
animal, xii
changes in, xi, xxi
ciliated, of organ of Corti, 767
contents of, xiii
of Deiters, 767
endogenous formation of, xvii
epithelial, lii, lvi, lviii
ethmoidal, 43
fat, lxv, lxvi
fissiparous multiplication of, xv, xvii
function of, in nutrition, xxv
furrowed and spinous of epithelium, lv
of grey matter of cerebellum, 528
hepatic, 873
CELLS—*continued.*
mastoid, 746
motion of protoplasm in, xix
of nerve-substance, cxxxix, cxlii, clxiv
nuclei of, xiii
multiplication of, xviii
olfactory, clv, 776
pigment, lxiii
of eye, 718, 719
production of, xv, xix
by division, xvii
in ovum, xv
in relation to formation of textures, xxi, xxiii
secreting, ccxx
spermatic, 976
structure of, xiii
vegetable, x
Cellular tissue, lxix. *See* AREOLAR TISSUE.
Cellulose, xiii
Cement of teeth, 785, 791
development of, 799
Centra of embryonic vertebræ, 21
Centre, phrenic, 245
Centrum geminum semicirculare, 550
ovale of Vieussens, 541
ovale minus, 541
of vertebræ, 22
Cephalic (κεφαλή, the head) vein, so called from having been supposed by the old physicians to be connected with the head, 466
Cephalogenesis (κεφαλή, the head; γένεσις, production), 72
Cerato-glossus (κέρας, a horn; γλῶσσα, a tongue) muscle, 186
CEREBELLUM (dim. of *cerebrum*, the brain), 522
corpus dentatum of, 526
crura of, 522, 527
development of, 575, 577
dissection of, 1051
falx of, 564
fissures of, 522, 523
hemispheres of, 522
internal structure of, 526
lobes of, 524
microscopic structure of, 529
peduncles of, 522, 527, 557
tentorium of, 563
veins of, 460
ventricle of, 525
vermiform process of, 522
weight of, 571
CEREBRO-SPINAL axis or centre, 501
blood-vessels of, 567
development of, 573
General Anatomy of, cxxxii
internal structure of, 518, 526, 554
membranes of, 562
fluid, 566
nerves, cxliv, 582. *See* NERVES.

CEREBRUM (the brain), 529
anfractuosities of, 531
base of, 536
convolutions of, 531
Foville's classification of, 534
Gratiolet's, 535
Leuret's, 535
commissures of,
crura of, 536, 556
development of, 575
dissection of, 1049
exterior of, 529
fibres of, 556.
ascending or peduncular, 555
transverse or commissural, 557
longitudinal or collateral, 557
Foville's views on, 558
fissures of, 530, 533, 547
grey matter of, 554, 559
gyri of, 531
hemispheres of, 529
internal parts of, 540
internal structure of, 554
lobes of, 529
peduncles of, 536, 566
sulci of, 531
veins of, 460
ventricles of, 543, 550
weight of, 571
Cerumen (*cera*, wax), 744
Cervical (*cervix*, a neck) arteries. *See* ARTERY
fasica, 196
nerves, 633, 636
plexus, 636
Cervico-facial division of facial nerve, 613
Cervix, or neck, of bladder, 947
uteri, 983
Chambers of eye, 737
Check ligaments, 126
Cheeks, 55, 779
CHEMICAL COMPOSITION of the different solids and fluids. *See* under the several titles of these.
Chest, muscles of, 240
position of parts of heart in, 313
Chiasma (χιαζω, I mark with the letter X; crossing or decussation), 584
Choledochus (χολη, bile; δεχομαι, I receive) duct, 868
Cholepyrrhine (χολη, bile; πυρρος, red), 879
Cholesterine (χολη, bile; στεαρ, fat), 879
in blood, xl
in nerve-tissue, cxxxii
Cholic (χολη, bile) acid, 879
Choloidic (χολη, bile; ειδος, form) acid, 879
Chondrin (χονδρος, cartilage), v, lxxxiv
Chondro-glossus (χονδρος, cartilage; γλωσσα, the tongue) muscle, 186
Chorda dorsalis, 16, 65
tympani, 611, 753
Chordæ tendineæ, 305
left ventricle, 313
Chordæ tendineæ, right ventricle, 310
Willisii, 462
Chorda, vocal, 910, 912
Choroid (χοριον, the chorion or investing membrane of the fœtus; ειδος, shape) plexuses, 548
development of, 581
of fourth ventricle, 526
of lateral ventricles, 543
tunic of eye, 716
pigment cells of, lxiv
structure of, 717
Chyle (χυλος, juice), xlviii
constitution of, xlix
globules, formation of, l
Chyliferous (*chylus*, chyle; *fero*, I carry) vessels, 491
Cilia (*cilium*, an eyelash), eyelashes, 707
vibratile, lix
Ciliary (*cilium*, an eyelash) arteries, 360, 721, 723
muscle, 721
nerves, 599, 600, 724, 725
part of retina, 730
processes, 717
vessels of, 722
motion, lix, lxi
cause of, lxii
Ciliated epithelium, liii, lviii
Cineritious (*cinis*, ashes) substance of nervous system, cxxxiii
Circle of Willis, 363
Circulation of blood, clxv
fœtal, 328
organs of, clxv, 297
pulmonary, clxvi, 297
systemic, clxvi, 297
Circulus articuli vasculosus, lxxxiv
major, 723
minor, 723
tonsillaris, 618
venosus of nipple, 1004
of retina, 729
Circumduction (*circum*, about; *duco*, I lead), 120
Circumferential fibro-cartilage, lxxxvi
Circumflexus (*circum*, around; *flecto*, I bend). *See* ARTERY, MUSCLE, and NERVE.
Claustrum (that which shuts off), 561
Clavicle (*clavicula*, dim. of *clavis*, a key), 77
ligaments of, 134
ossification of, 89, 90
Cleft, branchial, 64
Cleido-mastoid (κλεις, a key, or the clavicle; *mastoid* process) muscle, 193
Clinoid (κλινη, a bed; ειδος, shape) processes, 39, 42
Clitoris (κλειτορις, perhaps from κλειω, I enclose), 977
development of, 1001
erector muscles of, 266, 977
nerves of, 979
vessels of, 978

Cloacal (*cloaca*, a sewer) aperture, 1001
Coagulation (*coagulum*, a clot) of blood, xxvi, xliv
circumstances affecting, xlv
theory of, xlvi
Coccygeal (*coccyx*) artery, 429
gland, 697
ligament, 147
nerves. *See* NERVE.
Coccygeus (*coccyx*) muscle, 263
Coccyx (κοκκυξ, a cuckoo), 12
ligaments of, 147
ossification of, 20, 21
Cochlea (κοχλος, a shellfish, with a spiral shell), 755
aqueduct of, 38, 757
central column of, 755, 756
development of, 769
membranous structure of, 760
nerves of, 763
scalæ of, 757
spiral canal of, 755
vessels of, 767
Cochleariform (*cochleare*, a spoon; *forma*, shape) process, 58
Cœliac (κοιλια, the abdomen) artery or axis, 406, 837
Coins articulaires, of Corti, 765
Colic (κωλον, the colon or large intestine) arteries, 410, 412
Collar-bone, 77
Colles, fascia of, 259
Colliculus bulbi urethræ, 959
nervi optici, 726
Colloid (κολλα, glue; ειδος, shape) substances, Graham's researches on, vi
Colon (κωλον, originally limb), 853
arch of, 854
development of, 861
position of, 825
sigmoid flexure of, 854
Colour of arterial and venous blood, xlii
of lungs, 897
Colouring principles in blood, xxxiv
Columella cochleæ, 756
Column, posterior vesicular, 510
vertebral, 3
curves of, 13
development of, 15
form of, 14
ligaments of, 121
movements of, 125
Columnæ Bertini, 929
carneæ (fleshy columns), 305, 310, 312
recti, 858
rugarum, 981
Columnar epithelium, liii, lvi
layer of retina, 727
Columns of external abdominal ring, 1019
of rectum, 858
of spinal cord, 506
course of fibres in, 518
Columns of vagina, 987
Comes (a companion; pl. *comites*), clxxiii
nervi ischiadici, 429
nervi phrenici, 374
Commissure (*con*, together; *mitto*, I send) cerebral, anterior, 550, 557
great, 541, 557
middle or soft, 550, 580
posterior, 550, 557, 580
optic, 584
of spinal cord, 507
of vulva, 977
Compact tissue of bone, xc
Complex bones, lxxxviii
Complexus muscle, 237
Compressor (*con*, together; *premo*, I press). *See* MUSCLES.
Conarium (*conus*, the fruit of the fir), 552
Concha (κογχη, a shell), 740
Condyle (κονδυλος, a knuckle), lxxxviii
Condyles of femur, 102
of humerus, 79
of lower jaw, 52
of occipital bone, 31, 59
Condyloid portions of occipital bone, 29, 31
surfaces of tibia, 103
Cone, fibrous, 556
Cones of retina, 727
Congenital hernia, 1025
Conglobate (*con*, together; *globus*, a ball) glands, clxxxvi
Conglomerate (*con*, together; *glomero*, I gather in a round heap) glands, ccxxiv
Coni vasculosi, 970
Conjunctiva (*con*, together; *jungo*, I join), 708
Connecting fibro-cartilage, lxxxvi
Connective tissue, lxix
corpuscles of, lxxiii, clxxix
development of, lxxx
homogeneous, lxxix
jelly-like, lxxviii
retiform, lxxix
in nerve-substance, cxli
special varieties of, lxxviii
Conoid (κωνος, a cone; ειδος, shape) ligament, 135
Constrictor (*con*, together; *stringo*, I draw tight). *See* MUSCLES.
Contour lines of dentine, 788
of muscle, cxxxvi
Contractility of arteries, clxxi
of lymphatics, clxxxv
muscular, cxxix
of skin, ccxviii
of veins, clxxiv
vital, viii
Conus arteriosus, 310
Convolutions (*con*, together; *volvo*, I roll) of brain, 531

Convolutions, cerebral, classification of, 534
development of, 580
Coraco-acromial ligaments, 136
Coraco-brachialis muscle, 212
Coraco-clavicular ligament, 135
Coraco-humeral ligament, 137
Coracoid (κοραξ, a raven; εἶδος, shape) process of scapula, 76
Cord, genital, 996
gubernacular, 1000
spermatic, 963. *See* SPERMATIC CORD
spinal. *See* SPINAL CORD
Cordiform (*cor*, the heart; *forma*, shape) tendon of diaphragm, 245
Corium (skin), cciii
blood-vessels and lymphatics of, ccv
chemical composition of, ccvi
development of, ccvi
nerves of, ccvi
papillæ of, cciv
structure of, cciii
of mucous membrane, cxcvii
Cornea (*corneus*, horny), 714
opaca, 711
structure of, 715
nerves and vessels of, 716
Cornicula laryngis, 908
of hyoid bone, 52
Cornu Ammonis, 544
Cornua of hyoid bone, 52
sacral, 11
sphenoidal, 40
of thyroid cartilage, 906
of ventricles of brain, 543
Corona glandis, 955
radiata, 556
Coronal suture, 54
Coronary arteries. *See* ARTERIES
ligament, 827, 865
plexus. *See* PLEXUS
sinus, 310
vessels, 321
Coronoid fossa of humerus, 80
process of lower jaw, 52
of ulna, 82
Corpora albicantia, 537
development of, 581
Corpora Arantii, 308, 313
Corpora cavernosa clitoridis, 977
Corpora cavernosa penis, 956
arteries of, 428, 958
bulbs of, 956
covering of, 957
septum of, 956
structure of, 956
trabeculæ of, 957
veins of, 958
Corpora geniculata, 554
Corpora mammillaria, 537
Corpora Morgagni, 968
Corpora quadrigemina, 552
development of, 578
grey matter of, 561
Corpora striata, 550
development of, 580
grey matter of, 561
Corpus callosum, 530, 541
convolution of, 532
development of, 581
fibres of, 543, 557
peduncles of, 539, 542
Corpus ciliare, 515
Corpus dentatum of cerebellum, 526
of olivary body, 515
Corpus fimbriatum, 544, 546
Corpus Highmorianum, 968
Corpus luteum, 990
Corpus spongiosum urethræ, 958
structure of, 959
Corpuscles (*corpusculum*, pl. *-a*, dim. from *corpus*, a body) of blood, red, xxviii
chemical composition of, xxxiii, xli
formation of, l
proportion of, in blood, xxxvi
shape and size of, xxviii
structure of, xxix
pale, xxxi
of chyle, xlix
formation of, l
of connective tissue, lxxiii
ganglionic, cxxxix
of lymph, xlviii
formation of, l
Malpighian, of kidney, 930
of spleen, 887
of muscle, cxxi
of nervous substance. *See* Nerve-cells
tactile, cl, cli, ccvi
of thymus gland, 924
of thyroid body, 922
Corpuscula tactûs, cli, ccvi
Corrugator muscle, 173
Corti, membrane of, 761
organ of, 761, 764
rods or fibres of, 764
Cortical substance of brain, 555
of kidney, 929
of lymphatic glands, clxxxvii
of suprarenal bodies, 939
Costæ or ribs, 24
of scapula, 76
Costal cartilages, 26
structure of, lxxxiii
Costo-clavicular ligament, 134
Costo-central ligaments, 128
Costo-coracoid ligaments, 229
Costo-sternal ligaments, 130
Costo-transverse ligaments, 129
Costo-vertebral ligaments, 128
Costo-xiphoid ligaments, 130
Cotunnius, liquor of, 757
nerve of, 604
Cotyloid (κοτυλη, a cup; εἶδος, shape) cavity and notch, 96
ligament, 152

Cowper's glands, 963
development of, 1001
CRANIAL NERVES, classification of, 582
distribution of, 587
origin of, 583
first pair (o), 583, (d) 592
second pair (o), 584, (d) 592
third pair (o), 586, (d) 593
fourth pair (o), 586, (d) 594
fifth pair (o), 586, (d) 595
sixth pair (o), 586, (d) 610
seventh pair (o), 587, (d) 610
eighth pair, first part (o), 520, 587, (d) 615
second part (o), 520, 587, (d) 618
third part (o), 519, 587, (d) 625
ninth pair (o), 519, 587, (d) 626
Cranial sinuses, 461
Cranio-vertebral cavity, development of, 573
Cranium (κρανιον, the skull), 29
dissection of integument of, 1048
of interior of, 1049
of parts at base of, 1058
Creatin and creatinin (κρεας, flesh), xl, cxxviii
Cremaster (κρεμαω, I suspend), 251, 965, 1022
formation of, 1000
Cremasteric artery, 433
fascia, 965
Crest of bone, lxxxviii
external occipital, 30
nasal, 45
of ilium, 94
of os pubis, 95
Cribriform (*cribrum*, a sieve; *forma*, shape) fascia, 293, 1033
lamella of ethmoid bone, 43
of sclerotic, 712
of temporal bone, 38
Crico-arytenoid articulation, 910
muscles, 914
Cricoid (κρικος, a ring; ειδος, shape) cartilage, 906
Crico-thyroid artery, 348
ligaments, 909
muscles, 914
Crispation (*crispus*, crisp or curled), viii
Crista frontalis, 35
galli (cock's comb), 42
pubis, 95
urethræ, 961
vestibuli, 754
Crotaphite (κροταφος, the temple), 181
Crucial (*crux*, a cross) ligaments, 155
Cruor, xxxiv, xxxv
Crura of corpora cavernosa, 956
cerebri, 536
development of, 578
grey matter of, 561
cerebelli, 521, 522
development of, 577
Crura of clitoris, 977
of diaphragm, 243
of fornix, 545, 546
of penis, 956
Crural arch, 1033
deep, 258, 1033
canal, 293, 1034
septum, 1034
sheath, 293
Crureus muscle, 276
Crust of cerebral peduncle, 556
Crusta petrosa, 791
Crypt (κρυπτω, I conceal), ccxxii
multilocular, ccxxii
Crypts of Lieberkühn, 845
Cryptorchismus (κρυπτω, I conceal; ὀρχις, a testicle), 966
Crystalline (κρυσταλλος, ice or crystal) lens, 733. *See* Lens
Crystalloid substances, Graham's researches on, vi
Cuboid (κυβος, a cube; ειδος, shape) bone, 108
ligaments of, 162, 163
Cucullaris (*cucullus*, a hood) muscle, 200
Cul-de-sac of pleura, 894
recto-vesical, 857
of stomach, 831
Cuneiform (*cuneus*, a wedge; *forma*, shape) bones of foot, 109
ligaments of 163, 165
of hand, 84
cartilages, 905
process of ethmoid bone, 43
Cupola, 756
Cuspidate (*cuspis*, the point of a weapon) teeth, 781
Cuticle (*cutis*, the skin), cci
development of, ccvi
nutritive changes in, xxv
of enamel, 791
Cutis vera (true skin), cciii. *See* Corium and SKIN
Cuvier, ducts of, 483
Cylinder axis. *See* Axis, Cylinder
epithelium, lvi
Cylindrical bones, lxxxvii
Cystic (κυστις, a bladder) artery, 408
duct, 868, 878
Cytoblast (κυτος, a cell; βλαστος, a germ), xix
Cytoblastema (κυτος, a cell; βλασταυω, I germinate), xix
Cytogenous (κυτος, a cell; γενναω, I produce) connective tissue, lxxix

DARTOS (δαρτος, the skin of scrotum; δερω, I flay), 257, 964
fibres of, cxxvi
Decussation (*decusso*, I cut cross-wise) of optic nerves, 584
of pyramids, 515
De Graaf, vesicles of, 989
Deiters, cells of, 767

Deltoid (Δελτα, the letter Δ, or delta; εἶδος, shape) muscle, 208
Demours, membrane of, 715
Dens sapientiæ (wisdom tooth), 783
Dental arches, 780
  artery, 356
  canal, 52
  foramen, 52
  glands of Serres, 800
  grooves, 793
  nerves, 601, 608. *See* also TEETH
Denticulate ligament, 566
Dentine (*dens*, a tooth), 785
  development of, 797
  secondary, 792
Depressor. *See* MUSCLES
Derma (δερμα, skin), cciii
Descemet's membrane, 715
Descent of testicle, 1000
Detrusor (*de*, down; *trudo*, I thrust) muscle, 949
DEVELOPMENT of the several organs and tissues. *See* under these.
Dialysis (δια, apart; λυω, I loosen), vi
Diaphragm (δια, between; φρασσω, I fence), 243
  action of, 247
  pelvic, 263
Diaphragma oris, 184
Diaphragmatic nerve, 640
  plexus, 699
Diaphysis (δια, between; φυω, I grow), lxxxviii
Diapophysis (δια, apart; *apophysis*), 22
Diarthrosis (δια, between; ἀρθρον, a joint), 119
Diencephalon (δια, between; ἐγκεφαλον, the brain), 577
Digastric (δις, twice; γαστηρ, a belly) muscle, 183
  nerve, 613
Digestion, organs of, 779
  function of columnar epithelium in, lvii
Digital arteries. *See* ARTERY
  nerves. *See* NERVE.
Dilatator. *See* MUSCLES
Diploe (διπλους, double), xc, 60
  veins of, 465
Discus proligerus (*proles*, progeny; *gero*, I bear), 990
Disdiaclasts (δις, twice; διακλαω, I break), cxx
DISSECTION, general management of, 1047
  of abdomen, 1069
    cavity of, 1072, 1074
    viscera of, 1073
    wall of, anterior, 1070
      upper and posterior, 1075
  of ankle-joint, 1085
   arm, deep, 1064
    superficial, 1063
   axilla, 1061
   back, muscles of, 1063
DISSECTION—*continued.*
  of brachial region, 1064
   brain, 1049
   cervical region, 1052
   cranium, integument of, 1048
    interior of, 1049
    parts at base of, 1058
   face, deep, 1055
    superficial, 1054
   fifth nerve, 1057
   foot, articulations of, 1085
    dorsum of, 1084
    sole of, 1083
   forearm, articulations of, 1066
    front, 1064
    posterior, 1065
   genital organs, female, 1076
    male, 1072
   gluteal region, 1078
   hand, articulations of, 1066
    front, 1065
    posterior, 1065
   head and neck, 1048, 1059
   heart, 1067
   hip-joint, 1082
   knee-joint, 1085
   larynx, 1059
   leg, back of, 1082
    front of, 1084
   limb, lower, 1078
    upper, 1059
   mediastinum, posterior, 1068
   nares, 1059
   neck, anterior, 1053
    deep, 1059
    posterior, 1052
   orbit, 1056
   palate, 1058
   pectoral region, 1061
   pelvis, 1076
    ligaments of, 1078
    viscera of, 1077
   pericardium, 1067
   perinæum, 1069
    deep, 1040
   peritoneum, 1072
   pharynx, 1058
   pleura, 1066
   popliteal space, 1079
   scapular muscles, 1062
   shoulder-joint, 1064
   spinal cord, 1060
   sublingual region, 1057
   submaxillary region, 1057
   thigh, front of, 1080
   thorax, 1066
    articulations of, 1069
   tongue, 1058
Diverticulum (from *diverto*, I turn aside) of ileum, 841
Dolichocephalic (δολιχος, long; κεφαλη, the head) skulls, 73
Dorsal artery. *See* ARTERY
  ligaments. *See* LIGAMENT
  nerves. *See* NERVES

Dorsal veins. *See* VEINS
vertebræ, 5
Dorso-lumbar (*dorsum*, the back; *lumbus*, the loin) nerve, 658
Douglas, semilunar fold of, 251
Drum of ear, 744
Duct, bile, common, 868
cystic, 868, 878
hepatic, 867
Mullerian, 996
nasal, 709, 710
pancreatic, 882
supplementary, 883
parotid, 816
Stenson's, 816
of submaxillary gland, 817
thoracic, xlvii, cxc, 487
right, 488
vitelline, 859
Wharton's, 817
of Wolffian body, 992
Ductless glands, ccxxvi
Ducts of glands, in general, ccxxv
of Bellini, 930
biliary, 875
aberrant, 877
of Cuvier, 483
ejaculatory, 974
galactophorous, 1003
hepato-cystic, 869
of kidney, 930
of Rivini, 818
seminal, 974
of sublingual gland, 818
of sweat-glands, cclxxv
Ductus ad nasum, 710
arteriosus, 327, 328
closure of, 331
cochlearis, 761
communis choledochus, 868
venosus, 328, 483
fossa of, 864
Duodenum (*duodeni*, twelve; from being twelve finger-breadths in length), 839
development of, 861
dissection of, 1073
position of, 824
Dura mater, 562
development of, 581
structure of, 564
Dynamometer (δυναμις, strength; μετρον, a measure), 235

EAR, 740
development of, 768
dissection of, 1057
external, 740
auditory canal of, 743
structure of, 744
vessels and nerves of, 744
pinna of, 740
cartilage of, 741
ligaments of, 742
muscles of, 170, 742
EAR—*continued*.
pinna, nerves of, 743
vessels of, 743
internal, 753. *See* LABYRINTH
membranous, 757
osseous, 753
vessels of, 767
middle, 744. *See* TYMPANUM
bones of, 748
ligaments and muscles of, 749
lining membrane of, 751
vessels and nerves of, 752
Ear-wax, 744
Efferent nerves, cxxxii, clxii
vessels of kidney, 931
Ejaculator. *See* MUSCLES
Ejaculatory ducts, 974
Elastic cartilage, lxxxi, lxxxv
fibres of areolar tissue, lxx
lamina of cornea, 715
tissue, lxxvi
in arteries, clxix, clxx
Elbow, bones of, 79, 82
ligaments of, 140
movements of, 141
Electricity, manifestation of by muscles, cxxix
Elements, structural, of human body, iv
Eminence, frontal, 33
ilio-pectineal, 96
jugular, 31
nasal, 34
parietal, 32
supracondyloid, 79
Eminences of bones, lxxxviii
Eminentia collateralis, 544
papillaris, 746
pyramidalis, 754
Emotion, a stimulus of muscular action, cxxx
to nervous tissue, cxxxii
Emulgent (*emulgeo*, I milk or drain out) arteries, 414
Enamel membrane, 797
organ, 797
of teeth, 785, 789
development of 798
Enarthrosis (ἐν, in; ἀρθρον, a joint), 120
ENCEPHALON (ἐν, in; κεφαλη, the head), 513
blood-vessels of, 363, 370, 548, 567
development of, 575
grey matter of, 519, 527, 559
internal structure of, 526, 555
membranes of, 562
development of, 581
primary divisions of, 513
specific gravity of, 574
weight of, 568
parts of, 571
End-bulbs of nerves, cli, ccvi
Endocardium (ἐνδον, within; καρδια, the heart), 304
Endolymph (ἐνδον, within; *lympha*, water), 757

Endosteum (ἐνδον, within; ὀστεον, a bone), c
Ensiform (*ensis*, a sword; *forma*, shape) cartilage, 33
Epencephalon (ἐπι, on; ἐγκεφαλον, the brain), 577
Ependyma (ἐπι, on; ἐνδυμα, clothing), 543
Ephippium (ἐφιππιον, a saddle), 39
Epicondyle (ἐπι, on; *condyle*), 79
Epicranial (ἐπι, on; κρανιον, the skull) muscles, 169
Epidermis (ἐπι, on; δερμα, the skin), lii, cci
Epididymis (ἐπι, on; διδυμος, a testicle), 967
  canal of, 971
  development of, 999
Epigastric (ἐπι, on; γαστηρ, the stomach) artery. *See* ARTERY
  region, 824
    contents of, 826
Epiglottis (ἐπι, on; *glottis*), 908
  tubercle or cushion of, 911
Epihyal (ἐπι, on; *hyoid* bone) bone, 133
Epiphysis (ἐπι, on; φυω, I grow), lxxxviii
Epiphyses, formation of, cxii
Epiploical (*epiploon*, a name sometimes given to the omentum, from ἐπιπλεω, I sail, or float on) appendices, 830
Episternal (ἐπι, on; στερνον, the breast) nodules, 24
EPITHELIUM (ἐπι, on; θαλλω, I grow) in general, lii
  of air-passages, lix, 900
    alveoli of lungs, 900
    arachnoid, 566
    arteries, clxix
    bile-ducts, 877
    bronchia, 900
    capillaries, clxxvii
    capsules of Malpighian bodies, 932
    choroid, 718
  ciliated, lviii
  columnar, lvi
  of conjunctiva, 708
    cornea, 715, 716
    crypts of Lieberkühn, 846
    ducts of glands, lvii, lviii, ccxxv
    endocardium, 304
    Eustachian tube, 751
    eye-ball, liv
    Fallopian tube, 992
  flattened, liii
  furrowed and spinous cells of, lv
  of galactophorous ducts, 1004
    gall-bladder, lvii, 878
    glomeruli of kidney, 932
  glandular, lviii
  of intestines, lvii
    large, 856
    iris, 719
    labyrinth, 757
    lachrymal sac and duct, 710
EPITHELIUM—*continued.*
  lamellar, liii
  of larynx, 918
    lymphatics, clxxxiv
    Meibomian glands, 707
    membranous labyrinth, 758
    mouth, liv
    mucous membranes, lvii, cxcvii
    nasal fossæ, 775
  nerve-filaments in, clvi
  nutrition of, xxv
  of œsophagus, liv, 823
    palate, 813
    parotid duct, 816
  pavement, liii
  of pericardium, liii
    peritonæum, liii
    pharynx, 821
    pleura, liii
    prostatic gland and ducts, 954
  scaly, liii
  of seminiferous tubes, 971
    serous membranes, liii, cxcii
  spheroidal, lviii
  of stomach, lvii, 837
  stratified, liv
  of synovial membranes, cxciv
  tabular, liii
  tesselated, liii
  of throat, liv
    tongue, liv, 808
    trabeculæ of corpora cavernosa, 957
    trachea, 892
  transitional, lviii
  of tubuli of stomach, 837
    tympanum, 751
    ureters, 943
    urethra, liv, lvii, 962
    urinary bladder, 951
    uriniferous tubules, 930
    uterus, liv, lix, 985
    vagina, liv, 982
    vas deferens, 972
    vascular system, liii
    veins, cclxxiii
    ventricles of brain, 543
    vesiculæ seminales, 974
    villi of intestine, 844
    vulva, liv, 978
Epitrochlea (ἐπι, on; *trochlea*), 79
Equivocal cell-generation, xix
ERECTILE TISSUE, general characters of, clxxx
  of penis, 955
    vulva, 979
Erector. *See* MUSCLES
Ergot (Fr. a spur), 544
Ethmoid (ἠθμος, a sieve; εἰδος, shape) bone, 42
  development of, 69
Eustachian canal, 38, 59
  tube, 59, 747
  valve, 309
    development of, 325
Excito-motory movements, cxxxii

Excretion, ccxix
Expiration, physiology of, 248
Extension, 120
  of wrist, 228
Extensor. *See* MUSCLES
Extremities. *See* LIMBS
EYE, 705
  appendages of, 705
  aqueous humour of, 737
  ball or globe of, 710
  chambers of, 737
  ciliary muscle, 721
  circular sinus, 721
  coats of, external, 711
    middle, 716
  development of, 737
  lachrymal apparatus, 709
  lens of, 733
  ligamentum pectinatum, 721
  membranes, 711
    of Bruck, 717
    of capsule of lens, 733
    choroid, 716
    conjunctiva, 708
    cornea, 714
    of Demours or Descemet, 715
    hyaloid, 731
    iris, 718
    Jacob's, 726
    pigment, 718, 719
    pupillary, 721
    retina, 725
    Ruysch's, 717
    sclerotic, 711
  muscles moving the, 179
  nerve of. *See* NERVE, Optic; and Retina
  refracting media of, 711
  shape and size of, 711
  vessels and nerves of, 721
  vitreous body of, 731
Eyelashes, 707
Eyelids, 705
  cartilages of, 706
  conjunctiva of, 708
  development of, 739
  fissure of, 705
  glands of, 707
  ligaments of, 707
  muscles of, 171
  structure of, 706
Eye-teeth, 782

FACE, bones of, 44
  dissection of, 1054
  formation of, 66
  muscles of, 173, 174
  veins of, 455
Facial angle, 73
  artery, 349
  nerves, 587, 589, 610
Faisceaux innominés (Fr. anonymous fascicles), 518
Falciform (*falx*, a sickle or scythe; *forma*, shape) process, 1032
Fallopian tubes, 991
  development of, 997
  position of, 825
Fallopius, aqueduct of, 38
  hiatus of, 38, 61
  ligament of, 249
False membrane, cxciii
  pelvis, 97
  ribs, 24
Falx cerebelli, 524
  cerebri, 523
Fang of tooth, 780
FASCIA (a band), lxxiv, 168
  abdominal, 257
  anal, 260
  of arm, 229
  axillary, 230
  cervical, deep, 197
    superficial, 196
  of Colles, 259
  cremasteric, 253, 965
  cribriform, 293, 1031
  deep, 168
  dentata (dentated band), 548
  dorsal, 240
    of foot, 296
  of fore-arm, 230
    hand, 231
    head and neck, 196
  iliac, 259
  infundibuliform, 258, 965
  intercolumnar, 250, 965, 1020
  lata (broad fascia), 292, 1032
  of leg, 295
    lower limb, 292
  lumbar, 240
  masseteric, 197
  obturator, 261
  palmar, 231
  parotid, 197
  of pectoral region, 229
  pelvic, 260
  perineal, deep, 260, 1040
    superficial, 259, 1039
  plantar, 296
  prevertebral, 198
  propria, femoral, 1035
    inguinal, 965
  recto-vesical, 260
  spermatic, 965, 1020
  subpubic, 1040
  superficial or subcutaneous, 168
    of groin, 1018, 1031
  temporal, 197
  transversalis, 258, 1022
  of upper limb, 229
Fascicle (*fasciculus*, dim. from *fascis*, a bundle), round, 519
Fasciculi graciles (slender fascicles), 516, 518
  teretes (round fascicles), 517, 518, 521
  of muscle, cxvii
Fasciculus cuneatus (wedge-shaped fascicle or bundle), 516

Fasciculus—*continued.*
olivary, 516, 519, 521, 577
uncinatus (hook-shaped fascicle), 558
FAT, lxv
cells, lxvi
chemical composition of, lxvii
development of, lxviii
distribution of, lxv
uses of, lxviii
Fatty matters, vi
of blood, xl
Fauces (the throat), 779
isthmus of, 190
pillars of, 189
Femoral (*femur*, the thigh) arch, 1031
deep, 258, 1033
artery. *See* ARTERY
canal, 293, 1034
hernia. *See* Hernia
region, anterior, muscles of, 273
posterior, muscles of, 270
ring, 1033
vessels, sheath of, 1033
Femur, 100
compared with humerus, 116
ossification of, 111, 112
Fenestra (a window or opening) ovalis, 745
rotunda, 706
Fenestrated (perforated) membrane of arteries, clxix
Ferrein, pyramids of, 929
Fibra primitiva (primitive band), cxxxvi
Fibræ arciformes, 517
Fibres, axial, of nerve-tubes, cxxxvi
of cerebellum, 527
of cerebrum, 555
of Corti, 764
dental, 787
of lamellæ of bone, xcv
of medulla oblongata, 518
Müllerian, in retina, 728
of muscle, cxvii
structure of, cxviii
branched, cxxi
of nerve-tissue. *See* NERVE-FIBRES
nuclear, lxxi
of roots of spinal nerves, 511
Fibre-cells of involuntary muscle, cxxiv
in small vessels, clxxviii
Fibril (dim. of *fibra*, a fibre) of muscle, cxviii
Fibrillation of areolar tissue, lxxii
Fibrin (*fibra*, a fibre), vi
of blood, xxvii, xxxii, xxxvii
origin of, xxxviii
of chyle, xlix
Fibrinogen (*fibrin; γενναω*, I produce), xxxix
Fibrinogenous (*fibrin; γενναω*, I produce) substance, xxxix
Fibrinoplastic (*fibrin; πλασσω*, I form) substance, xxxix
Fibrinoplastin (*fibrin; πλασσω*, I form), xxxix
Fibro-cartilage, lxxxvi
intervertebral, 121
of knee, 155
of lower jaw, 133
pubic, 149
radio-ulnar, 138
scapulo-clavicular, 135
sterno-clavicular, 134
Fibro-serous membrane, cxcii
Fibrous cone, 556
structure of heart, 316
tissue, lxxiv
Fibro-vascular layer of corium, cciii
mucous membrane, cxcvii
Fibula (a brace, a clasp), 105
ligaments of, 158
ossification of, 111, 115
Fila acoustica, 757
Filamentous tissue, lxix
Filaments of areolar tissue, lxxi
of fibrous tissue, lxxv
spermatic, 976
Filiform papillæ of tongue, 807
Fillet, 519, 557
of corpus callosum, 557
Filum terminale of spinal cord, 502, 505
Fimbriæ (fringes) of Fallopian tube, 991
Fimbriated (fringed) extremity of Fallopian tube, 991
Fingers, bones of, 87
development of, 90, 93
fascia of, 222
muscles of, 217
Fissiparous (*findo*, I cleave; *pario*, I produce) propagation of cells, xvii
Fissura palpebrarum, 705
Fissure, calcarine, 536
of cerebellum, 523
of cerebrum, longitudinal, 530
convolution of, 533
internal perpendicular, 536
transverse, 547
vertical, 534
of ductus venosus, 864
of Glaser, 36, 37
of hippocampi, 533
incisor, 69
of kidney, 927
longitudinal, of liver, 864
occipital, 536
portal, 864
pterygo-maxillary, 57
of Rolando, 533
sphenoidal, 41, 57, 61
position of nerves in, 594
Sylvian, 530, 535
convolution of, 532
development of, 581
transverse, of liver, 864
umbilical, 864
of vena cava, 864
Fissures of liver, 864
of medulla oblongata, 514
of Santorini, 742
of spinal cord, 506

Flat bones, lxxxviii
Flattened epithelium, liii
Flesh, chemical composition of, xxxiii
Flexor. *See* MUSCLES
Flexure, hepatic, of colon, 853
  sigmoid, of colon, 854
    position of, 825
  splenic, of colon, 854
Floating ribs, 26
Flocculus (dim. of *floccus*, a lock of wool), 524, 577
Fluid, cerebro-spinal, 566
  prostatic, 954
  of serous cavities, cxciii
Fœtus, circulation in, 328
  lens in the, 735
  peculiarities of heart in, 327
    liver in, 879
    lungs in, 904
Folds, arytæno-epiglottidean, 910
  glosso-epiglottic, 805
  recto-uterine, 986
  recto-vesical, 947
  vesico-uterine, 986
Follicle (*folliculus*, dim. of *follis*, a bag), ccxxii
  of hair, ccix
    muscular fibres of, ccxi
Follicles, closed, of intestines, 856
  lenticular, of stomach, 837
  of teeth, 793
Follicular stage of development of teeth, 793
Fontanelles (*fons*, a fountain), 67
Foot, articulations of, 160
  bones of, 106
    compared with hand, 115
    ossification of, 110, 115
  dissection of, 1082, 1084, 1085
  fascia of, 296
  muscles of, 279
  nerves of, 683, 684
  vessels of, 446, 450
Foramen (*foro*, I pierce), carotid, 37, 59
  cæcum of frontal bone, 35, 61
    of medulla oblongata, 514
    of tongue, 805
  commune anterius of brain, 546
  dental, inferior, 52
  incisor, 44, 45
  infraorbital, 45, 56
  jugular, 59
  labial, 51
  lacerum anterius basis cranii, 59
    jugulare, 31
    orbitale, 41, 57
    posterius basis cranii, 38, 59, 61
  magnum, 29, 61
  mastoid, 37
  mental, 51, 56
  of Monro, 546
  obturator, 93, 96
  occipital, 29, 61
  optic, 41, 61
  ovale of sphenoid, 42, 59, 61
Foramen—*continued*.
  ovale of heart, 325, 328
      closure of, 331
      vestige of, 309, 312
    of pelvis, 93, 96
  parietal, 32
  rotundum, 42, 57, 61
  sacro-sciatic, great and small, 149
  spheno-palatine, 48, 58, 63
  spinosum, 42, 59, 61
  stylo-mastoid, 37
  supraorbital, 34, 56, 57
  suprascapular, 76
  thyroid, 93, 96
  of a vertebra, 5
  of Winslow, 827
Foramina of right auricle, 308
  condyloid, anterior, 31
    posterior, 31
  of diaphragm, 246
  of ethmoid bone, 43, 61
  intervertebral, 5
  malar, 49, 56, 57
  of nasal cavities, 61
  orbital, anterior and posterior, 34, 57
  palatine, anterior and posterior, 45, 59
    small, 47, 59
  sacral, anterior, 11
    posterior, 11
  of Scarpa, 45
  of Stenson, 45
  Thebesii, 309
Force, nervous, clxiii
Forces, vital, vii
Fore-arm, aponeurosis of, 230
  articulations of, 138
  bones of, 80
  compared with foot, 115
  development of, 90
  dissection of, 1065
  muscles of, 215, 218
  nerves of, 648, 685
  vessels of, 389, 395
Foreskin, 955
Form of pelvis, varieties in, 100
  of skull, varieties of, 72, 73
  of vertebral column, 14
Fornix (an arch or vault), 543, 545
  bulbs of, 537
  development of, 581
  fibres of, 559
Fossa of antihelix, 741
  canine, 45, 55
  coronoid, 80
  cystis felleæ (fossa of the gall-bladder), 865
  digastric, 36
  digital, 101
  ductus venosi, 864
  of gall-bladder, 865
  glenoid, 36, 57
  guttural, 59
  of helix, 741
  iliac, 95

Fossa—*continued.*
incisor of upper jaw, 45, 55
of lower jaw, 51
infraspinous, 74
innominata, 741
intercondyloid, 102
ischio-rectal, 261, 1043
jugular, 37
lachrymal, 34
myrtiform, 45
navicular, 41
navicularis of urethra, 962
vulva, 977
olecranon, 80
ovalis of heart, 309
of antihelix of ear, 741
pituitary, 39
pterygoid, 41
recto-vesical, 825
scaphoidea (boat-shaped fossa), 741
spheno-maxillary, 57
subscapular, 74
supraspinous, 74
temporal, 57
triangularis, 741
trochanteric, 101
of vena cava, 864
zygomatic, 57
Fossæ, inguinal, of peritoneum, 1024
of liver, 864
nasal, 61, 773
occipital, superior and inferior, 31
of skull, internal, 61
Fourchette (a fork), 977
Fovea (a pit or depression) centralis, 726
hemielliptica, 754
hemispherica, 754
ovalis, 309
trochlearis, 34
Foveæ glandulares, 33
Foveola (dim. of *fovea*, a pit) of renal papillæ, 930
Foville's classification of cerebral convolutions, 534
researches on fibres of cerebrum, 588
Fræna (pl. of *frænum*, a bridle) of ileo-cæcal valve, 853
of lips, 779
synovial, cxcv
Frænula, glosso-epiglottic, 805
of lips. *See* Fræna
Frænulum (dim. of *frænum*, a bridle) cerebri, 554
pudendi, 977
Frænum epiglottidis, 805
linguæ, 805
of prepuce, 955
Free ribs, 26
Frontal (*frons*, the forehead) bone, 33
ossification of, 67, 70
lobe of cerebrum, 535
processes in embryo, 65
sinus, 34, 64
suture, 55, 67
Fronto-parietal suture, 54
Fundus (the bottom of any thing) of bladder, inferior, 944, 946
superior, 945
of gall-bladder, 868
stomach, 831
uterus, 983
Fungiform (*fungus*, a mushroom; *forma*, shape) papillæ of tongue, 807
Funiculus (dim. of *funis*, a cord) of nerve, cxliv
Furcula (dim. of *furca*, a fork), 24
Furrowed band, 525
cells of epithelium, lv
Furrows of heart, 303

Gaertner, canals of, 992, 998
Galactophorous (γαλα, milk; φερω, I carry) ducts, 1003
Gall-bladder, 868
development of, 879
structure of, 878
varieties of, 868
Ganglia, General Anatomy of, cxxxii, cxli
structure of, cxlii
connection of nerve-fibres with, cxlii
of auditory nerve, cxlix
of cardiac nerves, 699
cranial, 688
of glosso-pharyngeal nerve, 616
lumbar, 696
lymphatic, clxxxvi
mesaraic, 702
of pneumo-gastric nerve, 618
sacral, 696
semilunar, 699
of spinal nerves, 630
sympathetic nerves, clviii, 686
thoracic, 693
of nerves of tongue, 812
vascular plexuses, 692
Gangliated cord, sympathetic, 686
cervical part, 688
lumbar part, 696
sacral part, 696
thoracic part, 693
Ganglion, Arnold's, 608
Bochdalek's, 602
cervical, lower, 693
middle, 692
upper, 688
ciliare, 599
diaphragmatic, 699
on facial nerve, 611
of fifth pair, or Gasserian, 596
geniculate, 611
impar, 697
intercaroticum, 692
jugular, 616
lenticular, 599
Meckel's, 603
ophthalmic, 599
otic, 608, 1057

GANGLION—*continued.*
petrous, 616
semilunare (syn. of the ophthalmic or lenticular ganglion), 599
spheno-palatine, 603, 1057
splanchnico-suprarenale, 699
submaxillary, 609
thyroid, 692
of Wrisberg, 698
Ganglion-globules, cxxxix
connection of nerves with, cxlii
Ganglionic corpuscles, cxxxix
nerves, cxxxiii, clviii
Gasserian ganglion, 596
Gastric (γαστηρ, the stomach) artery, 409
nerve, 623
Gastrocnemius (γαστηρ, the belly; κνημη, the leg) muscle, 283
Gastro-colic (γαστηρ, the stomach; κωλον, the colon) omentum, 829
Gastro-duodenal (γαστηρ, the stomach; *duodenum*) artery, 408
Gastro-epiploic (γαστηρ, the stomach; *epiploon*, the omentum) arteries, 408, 410
Gastro-hepatic (γαστηρ, the stomach; ἡπαρ, the liver) omentum, 827
Gastro-phrenic (γαστηρ, the stomach; φρην, the diaphragm) ligament, 829
Gastro-pulmonary (γαστηρ, the stomach; *pulmo*, a lung) mucous membrane, cxcvi
Gastro-splenic (γαστηρ, the stomach; σπλην, the spleen) omentum, 829
Gelatin, vi, lxxiii, lxxviii
Gelatinous nerve-fibres, cxxxviii
principles, vi
Gemellus (twin) muscle, 269
Generative organs, female, 977
male, 952
development of, 995
Genial (γενειον, the chin) tubercles, 185
Genio-hyo-glossus (γενειον, the chin; γλωσσα, the tongue) muscle, 185
Genio-hyoid (γενειον, the chin; ὑοειδης, *hyoid* bone) muscle, 185
Genital cord, 996
nerve-corpuscles, cli
organs, dissection of, 1072, 1076
Genito-crural nerve, 660
Genito-urinary mucous membrane, cxcvi
muscles, 263
Genu (a knee) of the corpus callosum, 542
Germinal matter, xxiv
membrane, 15
spot, xv, 990
vesicle, xv, 990
Gestation (*gesto*, I bear or carry), changes in uterus during, 987
Gimbernat's ligament, 250, 1031
Gingivæ (gums), 780
Ginglymus (γιγγλυμος, a hinge), 120
Giraldès, organ of, 973, 1001
Glabella (dim. of *glabra*, fem. of *glaber*, smooth), 34
GLANDS (*glans*, an acorn), Secreting, General Anatomy of, ccxviii
acini of, ccxxiv
agminated, cc
compound, ccxxii
conglobate, cc
conglomerate, ccxxiv
crypts, ccxxxii
ducts of, ccxxv
envelope of, ccxxv
follicles of, ccxxii
follicular, cc
formation of, ccxxi
forms of, ccxxii
lacunæ of, ccxxii
lobules of, ccxxii
lymphatics of, ccxxiv
of mucous membrane, cc
multilocular crypts, ccxxii
nerves of, ccxxv
racemose, ccxxii
reservoirs of, ccxxv
saccular, ccxxii
simple, ccxxii
solitary, cc
substance of, ccxxv
tubular compound, ccxxiv
simple, cc
vessels of, ccxxv
Glands, ductless, General Anatomy of, ccxxvi
enumeration of, ccxxvi
structure of, ccxxvi
varieties of, ccxxvi
GLAND, or GLANDS, antiprostatic, 963
arytenoid, 919
of Bartholin, 978
of bile-ducts, 877
Brunner's, 849
buccal, 780
ceruminous, 744
coccygeal, 697
Cowper's, 963, 1001
dental, 800
of Duverney, 978
epiglottidean, 919
gastric lenticular, 837
tubular, 836
kidney, 926. *See* KIDNEY
labial, 779
lachrymal, 709
of large intestine, 856
laryngeal, 918
of laryngeal pouches, 913
Littré, 963
liver, 862. *See* LIVER
mammary, 1002
Meibomian, 707
molar, 780
of mucous membrane, cc
of nose, 775
œsophageal, 823

GLAND, or GLANDS—*continued.*
palatine, 813
pancreas, 881. *See* PANCREAS
parotid, 814. *See* PAROTID
peptic, 837
of Peyer, 841, 846
of pharynx, 820
pineal, 552, 579
pituitary, 539
of prepuce, 955
prostate, 952. *See* PROSTATE
anterior, 963
salivary, 814
sebaceous, ccxvii
of skin, ccxv
small intestine, 845
solitary, cc, 849
sublingual, 817
submaxillary, 816
sudoriferous, ccxvi
suprarenal, 939
thymus, 923. *See* THYMUS
thyroid, 920. *See* THYROID
of tongue, 805, 809
tracheal, 892
of Tyson, 955
urethra, 962
uterine, 985
Wolffian (fœtal), 992
GLANDS, LYMPHATIC, General Anatomy of, clxxxvi
Descriptive Anatomy, 486
axillary, 497
bronchial, 495
cardiac, 495
cervical, 499
iliac, 490, 491
inguinal, 489
intercostal, 495
lumbar, 491
mediastinal, 495
mesenteric, 491
œsophageal, 495
popliteal, 489
sacral, 491
of thorax, 495
Glandula intercarotica, 692
socia parotidis, 815
Glandulæ Pacchioni, 567
ceruminosæ, 744
solitariæ of the intestine, 849
Glans (an acorn) clitoridis, 977
penis, 955
Glaser, fissure of, 36, 37
Glenoid (γληνη, a shallow pit of a bone; εἶδος, shape) cavity of scapula, 76
fossa of temporal bone, 36, 57
ligament, 137
Glisson's capsule, 867, 870
Globulin, xxxiv, xxxix
action of, in coagulation, xlvi
characters of, xxxv
Globus major and minor of the epididymis, 968
Glomerulus (dim. of *glomus*, a clue of thread) of kidney, 931
Glosso-epiglottic (γλωσσα, the tongue; *epiglottis*) folds or frænula, 805
Glosso-pharyngeal (γλωσσα, the tongue; φαρυγξ, the pharynx) nerve, 519, 589, 615
ganglia of, 616
Glottis (γλωττις, a tongue), 911
Glutæus (γλουτος, the buttock). *See* MUSCLES
Gluteal artery, 429
muscles, 266
nerve, 667, 673
Glycogen (γλυκυς, sweet; γενναω, I produce), vi
Goll, bands of, 535
Gomphosis (γομφος, a nail), 119
Graafian vesicles, 989
Gracilis (slender) muscle, 276
Graham's researches on dialysis, vi
Granular layer of dentine, 789
of retina, 727
Granules (*granum*, a grain), elementary, iv
in blood, xxxii, xliii
in nerve-substance, cxl
in muscular fibre, cxxi
Gratiolet's classification of cerebral convolutions, 535
Grey matter of cerebellum, 527
of cerebrum, 559
medulla oblongata, 519
pons Varolii, 521
spinal cord, 509
Gristle, lxxx
Groin, anatomy of, 1018
Groove, bicipital, 78
dental, 793
for Eustachian tube, 59
lachrymal, 46
musculo-spiral, 79
mylo-hyoid, 52
occipital, 37
scapular, 76
Growth, xxv
Gubernaculum (*guberno*, I steer or guide) testis, 1000
Gullet, 821
Gums, 780
Gustatory (*gusto*, I taste) cells, clvi
nerves, 606
Guttural (*guttur*, the throat) fossa, 59
Gyri (γυρος, a ring) of brain, 531
operti (covered convolutions), 532
Gyrus fornicatus (arched convolution), 532, 557
hippocampi (convolution of the hippocampus), 533

HABENULA perforata (perforated strip), 763
tecta vel arcuata (covered or arched strip), 763
Hæmal (αἷμα, blood) spine, 23

Hæmapoietic (αἷμα, blood; ποιέω, I make) function of liver, li
Hæmapophysis (αἷμα, blood; *apophysis*), 23
Hæmatin (αἷμα, blood), xxxiv
Hæmatoglobulin, xxxiv
Hæmatoidin (*hæmatin*; εἶδος, shape), xxxvi
Hæmin (αἷμα, blood), xxxvi
Hæmorrhoidal (αἷμα, blood; ῥέω, I flow) artery. *See* Artery.
nerves. *See* Nerves.
Hairs, ccviii
chemical nature of, ccxv
cuticle of, ccviii
development of, ccxii
distribution of, ccxiv
ending of nerve-fibres in, clv
follicles of, ccix
growth of, ccxi
medulla or pith of, ccviii
muscular fibres of, ccxi
reproduction of, ccxiv
root of, ccix
stem of, ccviii
Halitus (breath) of blood, xliv
Hamstring muscles, 270
Hamular process of sphenoid bone, 41
Hamulus (dim. of *hamus*, a hook) of cochlea, 756
lachrymalis, 50
Hand, bones of, 86
compared with foot, 115
dissection of, 1065
fasciæ of, 231
ligaments of, 142
muscles of, 225
nerves of, 649, 651
ossification of, 90, 93
vessels of, 391, 393, 397, 400
Harmonia (ἁρμόζω, I fit together), 119
Haunch, 93
Haversian canals, xci
spaces, xciii
Head, bones of, 29
dissection of, 1048
muscles of, 196
veins of, 455
of a bone, lxxxviii
Heart, 297
apex of, 302
arteries of, 321, 338
atria of, 304
auricles of, 302, 303, 304
capacity of, 322
development of, 323
fibres of, 317
left, 311
right, 308
septum of, 309
position of, 315
auriculæ or auricular appendages of, 304
bone of, 316
Heart—*continued.*
cavities of, clxv, 304
chordæ tendineæ of, 305, 306, 307, 310
columnæ carneæ of, 305, 312
covering of, 300
development of, 323
dissection of, 1067
endocardium of, 304
external form of, 302
fibrous rings of, 316
structure of, 316
fœtal, 323
foramina of. *See* Foramen, and Foramina
form of, 302
fossa ovalis of, 309
furrow, auriculo-ventricular, 303
longitudinal, 303
lining membrane of, 304
lymphatics of, 497
muscular fibres of, cxxvi, 317
musculi papillares of, 305, 307, 310, 313
pectinati of, 304, 312
nerves of, 321
orifices of, aortic, 313
auriculo-ventricular, left, 312
right, 308
positions of, 315
pulmonary, 310
size of, 322
of venæ cavæ, 308
position of, in the chest, 297, 302, 313
relation to surrounding parts, 297
septum, auricular, 309
fibres of, 320
ventricular, 310
serous coat, external, 300
sinus, coronary, 310
venosus, 304
size of, 321
structure of, 316
valves of, auriculo-ventricular, 305
left, 313
right, 310
Eustachian, 309, 325
mitral or bicuspid, 313
sigmoid or semilunar, 307
left, 313
right, 310
Thebesian, 310
tricuspid, 310
veins of, 321, 482
ventricles, in general, 302, 305
fibres of, 318
septum of, 310
ventricle of, left, 312
capacity of, 322
walls of, 312
right, 310
capacity of, 322
walls of, 310
weight of, 321

Hearts, lymphatic, cxc
Heel, 107
Helicine (ἑλιξ, a spiral) arteries, 958
Helicotrema (ἑλιξ, a spiral; τρημα, a hole), 755
Helix (ἑλιξ, a spiral), 741
fossa of, 741
muscles of, 742
process of, 742
Hemispheres, cerebellar, 522
cerebral, 529
Hemisphere vesicle, 580
Hepatic (ἡπαρ, the liver) artery, 408, 867, 871
cells, 873
duct, 867
nerve, 701
vein, 474, 871
blood of, xliii
Hepato-cystic (ἡπαρ, the liver; κυστις, a bladder) ducts, 869
Hernia (ἑρνος, a branch), congenital, 1025
femoral, anatomy of, 1031, 1080
coverings of, 1035
descent of, 1034
diagnosis of, 1035
operation on, 1036
infantile, 1026
inguinal, deep parts involved in, 1071
diagnosis of, 1029
direct or internal, 1027
in female, 1029
oblique or external, 1025
in female, 1026
operation for, 1030
parts concerned in, 1018
sac of, 1025
scrotal, 1025
surgical anatomy of parts concerned in, 1018
umbilical, cause of, 862
ventro-inguinal, 1027
Hesselbach, triangle of, 1027, 1029
Hiatus (an opening, from *hio*, v. n., I open) aorticus, 246
Fallopii, 38, 61
interosseus, 140
Highmore, antrum of, 46
Hilus (or *hilum*, the mark or scar on a bean) of kidney, 927, 928
of lymphatic glands, clxxxvii
of spleen, 883
Hilus-stroma, cxxxvii
Hip-joint, bones of, 96, 100
dissection of, 1082
ligaments of, 151
movements of, 153
muscles of, 266
Hippocampi, fissure of, 533
gyrus (convolution of the hippocampus), 533
tænia (band of the hippocampus), 544
Hippocampus (ἱπποκαμπος, from ἱππος, a horse, and καμπτω, I bend, a coiled sea animal) major, 544, 581
minor, 544, 581
Hippuric (ἱππος, a horse; οὐρον, urine) acid, xl, 939
Histogenetic (ἱστος, a tissue; γενναω, I produce) molecules, xxiv
Histology (ἱστος, a tissue; λογος, discourse), ii
Histolytic (ἱστος, a tissue; λυω, I dissolve) molecules, xxiv
Homologies of upper and lower limbs, 115
of vertebræ, 21
Homology (ὁμος, the same; λογος, proportion), 2
Homotypy (ὁμος, the same; τυπος, a type), 2
Horny substance of teeth, 792
Horse-shoe kidney, 927
Huguier, canal of, 745
Humerus (the shoulder), 78
compared with femur, 116
ossification of, 90
Humour, aqueous, 737
Hunter's canal, 294
Huxley's layer, ccxi
Hyaline (ὑαλος, glass) cartilage, lxxxi
coat of hair-follicle, ccx
Hyaloid (ὑαλος, glass; εἰδος, shape) membrane, 731
Hydatids of Morgagni, 968
Hydrocele, coagulation of fluid of, xxxviii
Hymen (ὑμην, a membrane), 978
Hyoglossus (ὑοειδης, *hyoid* bone; γλωσσα, tongue) muscle, 186
Hyoid (υ, the letter *upsilon*; εἰδος, shape) bone, 52
development of, 66, 70, 71
muscles of, 183, 191
Hypochondriac (ὑπο, under; χονδρος, cartilage) regions, 824
contents of, 826
Hypogastric (ὑπο, under; γαστηρ, the stomach) artery, 328, 420
nerve, 660
region, 824
contents of, 826
Hypoglossal (ὑπο, under; γλωσσα, the tongue) nerve, 519, 587, 589, 626
Hypophysis (ὑπο, under; φυω, I grow) cerebri, 539
Hypospadias (ὑπο, under; σπαω, I draw out), 1001
Hypothenar (ὑπο, under; θεναρ, the palm) eminence, 227
Hypoxanthin (ὑπο, under; ξανθος, yellow), xl, cxxviii

ILEO-CÆCAL valve, 852
Ileo-colic artery, 410
valve, 852
Ileum (εἰλεω, I roll), 840. *See* INTESTINE, small
position of, 824

Iliac arteries. *See* ARTERY
fossa, 95
region, muscles of, 271
Iliacus (*ilia*, the flank) muscle, 271
Ilio-aponeurotic muscle, 273
Ilio-costalis muscle, 234
Ilio-femoral ligament, 152
Ilio-hypogastric nerve, 660
Ilio-inguinal nerve, 660
Ilio-lumbar artery, 429
ligament, 147
Ilio-pectineal line, 95
Ilio-psoas muscle, 271
Ilium (*ilia*, the flanks), 94
ossification of, 110
Impressio coli on liver, 865
renalis on liver, 865
Incisor foramen, 44, 45
fissure, 69
teeth, 781
eruption of, 800, 803
Incisura (notch) of acetabulum, 96
ethmoidalis, 33
intertragica, 741
semilunaris, 76
of sternum, 24
Incus (an anvil), 748
development of, 66
ligament of, 749
Indicator muscle, 224
Infantile hernia, 1026
Infracostal muscles, 243
Inframaxillary nerve, 615
Infraorbital artery, 357
canal, 46
foramen, 45
Infraspinatus muscle, 210
Infraspinous artery, 373
fossa, 74
Infundibula (funnels) of kidney, 928
Infundibuliform fascia, 965
Infundibulum of brain, 539
of ethmoid bone, 43
heart, 310
lungs, 900
Ingrassias, wings of, 40
Inguinal (*inguen*, the groin) canal, 963, 1023
hernia, 1025, *See* Hernia
Innominate artery. *See* ARTERY
bone, 93
ossification of, 110
Inosinic acid, cxxviii
Inosite, cxxxiv
Interaccessorii muscles, 238
Interarticular fibro-cartilages and ligaments. *See* the various joints.
Interclavicular notch, 24
ligament, 134
Intercolumnar fascia, 965, 1020
Intercondyloid fossa, 102
Intercostal arteries. *See* ARTERY
muscles, 240, 241
nerves, 655
Interlaminar plexus, 850
Interlobular branches of hepatic artery, 873
Intermaxillary bone, 70
Intermetatarsal ligaments, 165
Internodia (*inter*, between; *nodus*, a knot), 87
Interossei. *See* MUSCLES
Interosseous arteries. *See* ARTERY
ligament. *See* LIGAMENTS
Interpeduncular space, 536
Interspinales muscles, 238
Interspinous ligament, 124
Intertransversales muscles, 238
Intertransverse ligaments, 125
Intertrochanteric line, 101
Intertubular stroma of kidney, 938
substance of teeth, 787
Intervertebral discs, 121
foramina, 5
INTESTINE, large, 851
cæcum, 852
colon, 853
development of, 861
dissection of, 1073
divisions of, 851
epithelium of, 856
follicles of, 856
glands of, 856
length and extent of, 851
lymphatics of, 858
mucous membrane of, 855, 858
muscular coat of, 854, 858
position of, 825
rectum, 856. *See* Rectum
structure of, 854, 858
tubuli of, 856
valve of, 852
vessels and nerves of, 856, 858
INTESTINE, small, 838
absorbents of, 850
areolar coat of, 841
convolutions of, 840
crypts of, 845
development of, 861
dissection of, 1072
divisions of, 838
duodenum, 839
epithelium of, 844, 846
glands of, 845
agminated or Peyer's, 846
Brunner's, 849
crypts of Lieberkühn, 845
solitary, 849
ileum, 840
jejunum, 840
lacteals of, 844, 847
length and extent of, 838
mesentery of, 838
mucous membrane of, 842
muscular coat of, 841
nerves of, 850
peristaltic movement of, 841
position of, 824
serous coat of, 841
structure of, 841

INTESTINE, small—*continued.*
valves of, 842
vessels, 843, 849
villi of, 842
Intracartilaginous ossification, ciii., cvi
Intralobular veins, 870, 871
Intramembranous ossification, ciii
Involuntary muscles, cxxiv
Iris (ἶρις, a rainbow), 718
blood-vessels of, 723, 726
nerves of, 724
pigmentary elements of, 719
pillars of, 716
structure of, 718
Iron in blood, xxxiv
Irritability, muscular, cxxix
duration after death, cxxx
Ischio-cavernosus muscle, 264
Ischio-rectal fossa, 269, 1043
region, 1037
Ischium (ἰσχίον, the hip), 96
ossification of, 110, 112
Island of Reil, 532, 535
Isotropic substance in muscle, cxx
Isthmus faucium, 90, 779
of thyroid body, 920, 921
Isthmus Vieussenii, 309
Ivory of teeth, 785

JACOB'S membrane, 726
Jaw, changes in during dentition, 804
lower, 51
development of, 70, 71
ligaments of, 132
muscles of, 181
upper, 44
development of, 69, 71
Jejunum (*jejunus*, empty), 840. *See* INTESTINE, small
position of, 824
Joint, ankle, 158
clavicular, 134
crico-thyroid, 909
elbow, 140
foot, 160
hand, 142
hip, 151
jaw, lower, 132
knee, 153
occipito-vertebral, 125
pelvic, 147
radio-ulnar, 138
of ribs, 128
shoulder, 136
vertebral, 121
wrist, 142
Joints in general, 118
motions of bones in, 120
synovial membranes of, cxciii
Jugular eminence, 31
foramen, 59
fossa, 37
vein. *See* VEIN

KERATIN (κέρας, horn), ccxiii
Kerato-cricoid (κέρας, a horn; *cricoid* cartilage) muscle, 915
Kerkring, valves of, 842
KIDNEYS, 926
adipose capsule of, 926
calyces or infundibula of, 928
coat of, fibrous, 928
corpuscles of, Malpighian, 929, 930
cortical substance of, 929
development of, 993
excretory duct of, 928
form of, 927
glomeruli of, 931
hilus or fissure of, 927, 928
horseshoe, 927
intertubular stroma of, 938
lymphatics of, 495, 938
medullary substance of, 929
nerves of, 938
papillæ of, 928, 929
pelvis of, 928
position of, 926
primitive or primordial, 993
pyramids of, Ferrein's, 929
Malpighi's, 929
sinus of, 928
size of, 926
relative, in fœtus, 994
structure of, 928
surfaces and borders of, 927
tubuli of, 929
convoluted, 930
looped, 930
origin and course of, 933
straight, 930
structure of, 930
varieties of, 927
vessels of, 935
distribution of, 931, 937
weight of, 926
Knee-joint, bones of, 103
dissection of, 1085
ligaments, of 153
movements of, 157
Knee-pan, 103
Kreatin (κρέας, flesh), cxxviii, cxxxiv

LABIA pudendi, 977
majora, 977
development of, 1001
minora, 977
Labial artery, 350
glands, 779
Labium tympanicum, 760, 761
vestibulare, 761
Labyrinth (λαβύρινθος, a maze, from its complex structure), 753
development of, 768
membranous, 757
osseous, 753
lining membrane of, 757
vessels of, 767

Lacerti of muscle, cxvi
Lachrymal apparatus, 709
 artery, 360
 bone, 50
  ossification of, 70, 71
 canals, 709
 gland, 709
 nerve, 597
 sac, 709
LACTEALS (*lac*, milk), 491
 General Anatomy of, xlvii, clxxxvi
 origin of, clxxxvii
 plexuses of, in intestine, 846
 relation to villi, 844
Lactiferous (*lac*, milk; *fero*, I carry) ducts, 1003
Lacuna, ccxxii
 magna, 963
Lacunæ in bone, xciv
 formation of, cx
Lacunar origin of lymphatics, clxxxiii
Lambdoidal (Λ, the letter *lambda*; εἶδος, shape) suture, 54
Lamella, cribriform, 43
Lamellæ of bone, xc, xcv
Lamina of a vertebra, 4
 cinerea (grey layer), 539
 cribrosa (a plate perforated like a sieve) of sclerotic, 712
  of temporal bone, 38
 denticulate, of cochlea, 761
 elastic, of cornea, 715
 fusca, 716
 reticularis, 765
 spiral of cochlea, 755
 spiralis membranacea, 760
 spiralis ossea, 756
Laminæ or plates of vertebræ, 4, 6, 8, 9
Laminated tubercle, 525
Lancisi, nerves of, 542
Lanugo (wool or down), ccxiii
LARYNX (λαρυγξ, the larynx), 905
 cartilages of, 905
  arytenoid, 907
  cricoid, 906
  cuneiform, 908
  ossification of, 919
  Santorini's, 908
  structure of, 909
  thyroid, 906
  of Wrisberg, 908
 development of, 919
 dissection of, 1058
 glands of, 913, 918
 growth of, 919
 interior of, 910
 ligaments of, 909. *See* LIGAMENTS
 mucous membrane of, 918
 muscles of, 914
  action of, 917
 nerves of, 622, 919
 pouches of, 913
 ventricles or sinuses of, 913
 vessels of, 348, 371, 919
 vocal cords of, 912
Latissimus dorsi muscle, 200
Laxator tympani muscle, 750
Layer, columnar, of retina, 727
 granular, of dentine, 789
 internuclear of retina, 728
 nervous of retina, 728
Leg, aponeurosis of, 294
 articulations of, 158
 bones of, 103, 105
 dissection of, 1082, 1084
 muscles of, 279, 282
 nerves of, 683
Lemniscus (λημνισκος, a band), 557
Lens (a lentil), crystalline, 733
 capsule of, 733
 changes in by age, 735
 development of, 737
 fibres of, 735
 structure of, 734
 suspensory ligament of, 736
Lenticular (dim. from *lens*) follicles of stomach, 837
 ganglion, 599
Leucin (λευκος, white), xl, cxxxiv
Levator. *See* MUSCLES
Lex progressûs, clxi
Lieberkühn's crypts, 845
Lienculi (little spleens), 884
Life, application of the term, vii
Ligamenta arcuata, 243
 lata, 986
 subflava, lxxvii, 123
 suspensoria, 229
 vaginalia, 213
LIGAMENTS (*ligo*, I bind), acromio-clavicular, 134
 of ankle, annular, anterior, external, and internal, 295
  anterior, 160
  dissection of, 1085
  external and internal, 159
  lateral, 159
  posterior, 160
 arytenoid, 909
 astragalo-calcaneal, external, 161
  interosseous, 160
  posterior, 160
 astragalo-scaphoid, 161
 atlanto-axial, anterior and posterior, 128
 of atlas, transverse, 125
 of bladder, false, 945, 947
  true, 945
   anterior, 260, 952
   lateral, 261
 calcaneo-cuboid, dorsal or superior, 162
  internal or interosseous, 162
  inferior, 162
  short or deep-seated, 162
  superior, 162
 calcaneo-scaphoid, external, interosseous, or dorsal, 161
  inferior, or plantar, 161

LIGAMENTS—*continued.*
carpal, annular, anterior and posterior, 144, 231
dissection of, 1066
dorsal, 142, 143
interosseous, 142, 143
lateral, 142
palmar, 142, 143
carpo-metacarpal, 144
central of spinal cord, 505
coccygeal, 147
of colon, 854
conoid, 135
coracoid, 136
coraco-acromial, 136
clavicular, 135
humeral, 137
costo-clavicular, 134
coracoid, 229
sternal, 130
transverse, 129
anterior or long, 130
middle or interosseous, 130
posterior, 129
vertebral, 128
xiphoid, 130
cotyloid, 132
crico-arytenoid, 910
thyroid, 909
crucial, 155
cruciform, 126
of cuboid bone, 162, 163
of cuneiform bones, 163
of elbow, 140
anterior, 141
dissection of, 1066
lateral, external and internal, 141
posterior, 141
of Fallopius, 249
of fingers and toes, transverse, 296
of foot, 160
dissection of, 1085
of forearm, 138
dissection of, 1066
gastro-phrenic, 829
Gimbernat's, 250, 1031
glenoid, 137
of hand, 142
dissection of, 1066
of hip-joint, accessory, 152
capsular, 152
cotyloid, 152
dissection of, 1082
ilio-femoral, 152
interarticular or round, 152
transverse, 152
hyo-epiglottic, 908
ilio-femoral, 152
lumbar, 147
of incus, 749
interclavicular, 134
interspinous, 124
intertransverse, 125
intervertebral, 121, 147

LIGAMENTS—*continued.*
of knee-joint, 153
capsular, 156
crucial, 155
dissection of, 1085
lateral, external and internal, 154
posterior, 155
transverse, 156
of larynx, 909
of leg, 158
of liver, broad, 827, 865
coronary, 827, 865
falciform, 827, 865
round, 827, 865
suspensory, 827, 865
triangular, 827, 865
of lower jaw, 132
of lower limb, 151
of malleus, posterior, 750
suspensory, 749
metacarpal, dorsal, 145
interosseous, 145
palmar, 145
of thumb, 145
metacarpo-phalangeal, 145
anterior, 145
lateral, 145
metatarsal, 165
transverse, 166
metatarso-phalangeal, 166
obturator, 150
occipito-atlantal, 128
axial, 128
odontoid, 126
middle, 127
orbicular, 138
of stapes, 749
of ovary, 986, 988
palpebral, 707
of patella, 155
lateral, 156
of pelvis, 147, 1078
peritoneal, 826
peroneo-tibial, superior, 158
inferior, 159
transverse, 159
of phalanges, fingers, 146
toes, 166
of pinna of ear, 742
Poupart's, 249, 1031
pterygo-maxillary, 176
pubic, anterior, 149
inferior, 150
posterior, 149
superior, 149
pubo-prostatic, 952
radio-carpal, 142
radio-ulnar, 138
of ribs, 128
sacro-coccygeal, anterior and posterior, 147
sacro-iliac, anterior, 148
oblique, 148
posterior, 147

LIGAMENTS—*continued.*
sacro-sciatic, anterior, 148
posterior, 148
sacro-vertebral, 147
of scaphoid bone, 161, 163
of scapula, 136
scapulo-clavicular, 134
of shoulder-joint, 136
dissection of, 1064
capsular, 136
glenoid, 137
spiral, 761
of stapes, 749
stellate, 128
of sternum, 131
sterno-clavicular, 134
stylo-hyoid, 52, 133
stylo-maxillary, 133, 197
subpubic, 150
supraspinous, 124
suprascapular, 136
suspensory, crystalline lens, 731, 736
liver, 827, 865
malleus, 749
of odontoid process, 727
penis, 257, 955
talo-scaphoid, 161
tarsal, of eyelid, 707
of foot, 160
tarso-metatarsal, 165
temporo-maxillary, 132
terminal, of spinal cord, 502, 505
thyro-arytenoid, inferior and superior, 910
thyro-epiglottic, 908
thyro-hyoid, 909
tibio-fibular, inferior, 158
superior, 159
trapezoid, 135
of tympanum, 749
of upper limb, 134
of urethra, triangular, 260, 1040
of uterus, 985
anterior and posterior, 986
broad, 986
round, 986
vertebral, 122, 124
dissection of, 1069
of wrist, 142
yellow, of spine, 123
Ligamentum arcuatum externum, 244
arcuatum internum, 244
breve, 218
colli costæ, 130
cruciatum cruris, 295
denticulatum, 566
latum pulmonis, 894
mucosum, 157
nuchæ, lxxvi, 125
patellæ, 155
pectinatum, 721
proprium anterius, 136
posterius, 136
rhomboides, 134
spirale, 764
LIGAMENTS—*continued.*
suspensorium (of bladder), 947
dentis (of the odontoid process), 127
teres of hip joint, 152
teres uteri, 987
transversum cruris, 295
LIGATURE of the brachial artery, 1010
carotid, common, 1005
femoral, 1015
iliac, common, 1012
external, 1014
internal, 1014
subclavian, 1007
Ligula, 517
Limb, lower, articulations of, 151
bones of, 93
development of, 110
dissection of, 1078
muscles of, 266
veins of, 475
upper, articulations of, 134
bones of, 74
development of, 88
dissection of, 1059
muscles of, 198
veins of, 465
Limbs, homologies of, 115
relation to segments of trunk, 117
Limbus laminæ spiralis, 761, 763
luteus of the retina, 726
Line of bone, lxxxviii
curved, of ilium, 94, 95
ilio-pectineal, 95, 96
intertrochanteric, 101
occipital, curved, 30, 31
pectineal, 96
popliteal, 104
Linea alba, 255
aspera, 101
splendens, 567
Lineæ semilunares, 255
transversæ, 255
Lines of enamel, 789
contour, of dentine, 788
Lingual artery, 348, 812
Lingula, 42
Lips, 779
arteries of, 350
muscles of, 175
Liquor Cotunnii, 757
Morgagni, 733
sanguinis, xxvii, xxxii, xxxvii
seminis, 975
Lister's researches on movements in pigment-cells, xx
on coagulation of blood, xlvi, xlvii
Lithotomy, 1043
LIVER, 862
accessory, 869
capillaries of, 873
cells of, 873
changes in, after birth, 880
chemical characters of, 863
coats of, 869

Liver—*continued.*
congestion of, 873
development of, 863, 879
dissection of, 1074
ducts of, 868
aberrant, 877
commencement of, 875
structure of, 877
excretory apparatus of, 867
fissures of, 864
fœtal, peculiarities of, 879
fossæ of, 864
hæmapoietic function of, li
ligaments of, 824, 865
lobes of, 864
lobules of, 870
lymphatics of, 493, 867
nerves of, 867
position of, 824, 865
size of, 862
specific gravity of, 863
structure of, 869
surfaces of, 863
varieties in the, 868
vessels of, 867
distribution of, 871
in the fœtus, 880
weight of, 863
Lobe, biventral, 524
central of cerebellum, 525
of cerebrum, 535
curved, 536
frontal, 535
fronto-parietal, 536
maxillary, 65
occipital, 535, 536
occipito-temporal, 536
parietal, 535
quadrate, 524
slender, 524
subpeduncular, 524
temporo-sphenoidal, 535
Lobes of cerebellum, 524
of cerebrum, 529
Gratiolet's arrangement of, 535
liver, 864
lung, 895
prostate, 953
testis, 969
thymus gland, 923
thyroid body, 920
Lobule of ear, 741
of pneumo-gastric nerve, 524
Lobules of liver, 870
of lungs, 898
Lobuli testis, 969
Lobulus caudatus, 864
quadratus, 864
Spigelii, 864
Locus niger, 556, 561
perforatus anticus, 531, 539
perforatus posterior, 536
Lower, tubercle of, 310
Luette vesicale (Fr., uvula of the bladder), 948
Lumbar arteries, 417
ganglia, 696
region, 417
contents of, 417
plexus, cxlvi
vertebræ, 6
Lumbricales (*lumbricus*, an earthworm) muscles, 219, 287
Lungs, 894
air-cells of, 899
tubes of, 898
subdivision of, 900
capacity of, 896
capillaries of, 902
changes at birth in, 904
colour of, 897, 905
development of, 904
fœtal, 904
form of, 894
lobes of, 895
lobules of, 898
lymphatics of, 496
nerves of, 903
roots of, 897
size and weight of, 895
specific gravity of, 897
structure of, 898
surfaces and borders of, 895
texture of, 897
vessels of, pulmonary, 898
bronchial, 903
Lunula (dim. of *luna*) of nails, ccvi
of valves of heart, 308
Lymph (*lympha*, water), xlviii
of blood, or liquor sanguinis, xxvii
channels, clxxxiii, clxxxviii
chemical composition of, xlix
corpuscles, xlviii
formation of, l
duct, right, 488
plasma of, xlviii
sinus, clxxxvii
Lymphatic system, General Anatomy of, clxxxii
glands, xlvii, clxxxvi
structure of, clxxxvi
vessels of, clxxxviii
hearts, cxc
vessels, xlvii, clxxxii
afferent, clxxxvi, clxxxix
in areolar tissue, lxxiii
of bones, cii
coats of, clxxxiv
development of, cxci
distribution of, clxxxii
efferent, clxxxvi, clxxxix
lacteal. *See* Lacteals
lacunar origin of, clxxxiii
of mucous membrane, cxcviii
of muscle, cxxiii
orifices of, clxxxv
origin of, clxxxii
plexiform, clxxxii
of serous membrane, cxcii
of skin, ccv

LYMPHATIC vessels—*continued.*
structure of, clxxxiv
termination of, cxc
valves of, clxxxv
vessels of, clxxxiv
vital properties of, clxxxv
LYMPHATICS, Descriptive Anatomy of, 486
of the abdomen, 490, 491
back, 499
bladder, 495, 951
chest, 499
cranium, 499
face, 499
head and neck, 499
heart, 497
intercostal, 496
intestines, large, 858
kidneys, 495, 938
larynx, 919
limb, lower, 488, 490
upper, 497, 498
liver, 493
lungs, 496
œsophagus, 497
pancreas, 493
pelvis, 490
penis, 490, 959
pia mater, 564
prostate, 954
rectum, 493, 858
scrotum, 490, 967
spleen, 493, 887
sternum, 496
stomach, 493, 838
suprarenal capsules, 495, 941
testicle, 495, 975
thorax, 495
thymus gland, 497, 925
thyroid gland, 922
trunk, lower half, 488, 490
ureter, 495
uterus, 495, 987
vulva, 980
Lymphoid (*lympha*; εἶδος, shape) tissue, cxcix, cc
Lyra, 547

MACULA germinativa (germinal spot), xv, 990
lutea (yellow spot), 726
colour of, 730
Madder, effect of, on bone, cxiii
Malar (*mala*, the cheek) arch, 57
artery, 360
bone, 49
ossification of, 70, 71
foramina, 49, 56, 57
nerves, 600
process, 45
Malleolar (*malleolus*, the ankle) arteries, 449, 450
Malleolus (dim. of *malleus*, a hammer; the ankle), external, 105
internal, 104
Malleus (a hammer), 748
ligaments of, 749, 750
ossification of, 66
Malpighian corpuscles of kidney, 929, 930
of spleen, 887
layer of skin, lv, ccii
pyramids of kidney, 929
Mammary (*mamma*, the breast) artery. *See* ARTERY
glands, in female, 1002
in male, 1004
structure of, 1003
varieties of, 1004
vessels and nerves of, 1004
veins. *See* VEINS
Mantle of cerebral vesicle, 580
Manubrium (a handle) of malleus, 748
of sternum, 23, 24
Marrow of bone, c
spinal. *See* SPINAL CORD
Masseter (μασσαομαι, I chew) muscle, 181
Masseteric (*masseter*) artery, 356
fascia, 197
nerve, 605
Mastoid (μαστος, a nipple; εἶδος, form) artery, 351
cells, 746
foramen, 37
process, 36
Mastoido-humeral muscle, 193
Matrix of cartilage, lxxxi
intercellular, xxiii
of nails, ccvi
Maxillary (*maxilla*, a jaw) artery. *See* ARTERY
bone, lower, 51
ossification of, 70, 71
upper, 44
ossification of, 69, 71
lobe, 65
nerves. *See* NERVES
sinus, 46, 64
vein, 457
Meatus (*meo*, I pass), lxxxviii
auditory, external, 37, 743
in infant, 744
structure of, 744
vessels and nerves of, 744
internal, 38, 61
of nose, inferior, 63, 774
middle, 43, 63, 774
superior, 43, 63, 774
urinarius (urinary passage) in female, 978, 980
Meckel's cartilage, 66, 769
ganglion, 603
Median artery, 369, 391
basilic (βασιλικος, royal) vein, 466, 467
cephalic (κεφαλη, the head) vein, 466, 467
cutaneous vein, 466, 467
nerve, 649
vein, 467

Mediastinal arteries, 374, 402
veins, 454
Mediastinum (*medius*, the middle; *sto*, I stand), 297, 893
posterior, dissection of, 1068
testis, 969
MEDULLA OBLONGATA, 513, 514
columns of, 514
course of, 518
development of, 577
fibres of, 518
fissures of, 514
grey matter of, 519
weight of, 571
Medulla ossium (marrow of bones) c
of hair, ccviii
of tongue, 811
Medulla spinalis. *See* SPINAL CORD
Medullary canal of bone, formation of, cxi
sheath of nerve-fibre, cxxxvi
spaces, cix
substance of encephalon, 555
of kidney, 929
of lymphatic glands, cxxxvii
Medullated nerve-fibres, cxxxv
Meibomian glands, 707
Membrana basilaris, 760, 763
fusca, 711, 723
granulosa, 990
limitans, 728
nictitans, 706
propria, of mucous membranes, cxcvii
pupillaris, 721, 739
sacciformis, 139
of secreting glands, ccxxi, ccxxiv
of skin, cciii
tectoria, 761, 767
tympani, 745
secondary, 746
vestibularis, 761
Membrane, arachnoid, 565
basement. *See* Basement membrane
of black pigment, 718
of Bruch, 717
choroid, 716
of Corti, 761
costo-coracoid, 229
crico-thyroid, 909
of Demours or Descemet, 715
fenestrated or perforated, clxix
germinal, 15
hyaloid, 731
Jacob's, 726
limitary, of mucous membrane, cxcvii
limiting, of retina, 728
lining, of osseous labyrinth, 757
of tympanum, 751
Nasmyth's, 791
ossification in, ciii
periodontal, 780
pituitary, 774
preformative, 797
Membrane—*continued.*
primary, of mucous membrane, cxcvii
pupillary, 721, 739
of Reissner, 761, 767
Schneiderian, 774
thyro-hyoid, 909
MEMBRANES OF THE BRAIN AND SPINAL CORD, 562
development of, 581
mucous, serous, &c. *See* MUCOUS and SEROUS MEMBRANES, &c.
Membranous cochlea, 760
labyrinth, 757
semicircular canals, 758
tube of nerve-fibre, cxxxvi
vestibule, 757
Meningeal artery. *See* ARTERY
vein. *See* VEIN
Meninges (μηνιγξ, a membrane), 562
development of, 581
Menstruation, uterus during, 987
Mental (*mentum*, the chin) foramen, 51
nerve, 608
Mesencephalon (μεσος, middle; ἐγκεφαλον, the brain), 577
Mesenteric (μεσος, middle; ἐντερον, intestine) artery, 410. *See* ARTERY
glands, 491
plexus, 702
veins, 481
Mesentery (μεσος, middle; ἐντερον, intestine), 824, 826
development of, 859
Mesial (μεσος, middle) plane, 2
plate in embryo, 859
Mesocæcum (μεσος, middle; *cæcum*), 826, 830
Mesocephalon (μεσος, middle; κεφαλη, the head), 521
Mesocolon (μεσος, middle; κωλον, the colon), 826
sigmoid, 830
transverse, 829
Mesogastrium (μεσος, middle; γαστηρ, the stomach), 861
Mesorchium (μεσος, middle; ὀρχις, a testicle), 965
Mesorectum (μεσος, middle; *rectum*), 826, 830, 856
Metabolic (μεταβαλλω, I change) force, viii
Metacarpal artery, 391, 398
Metacarpus (μετα, beyond; καρπος, the wrist), 86
ligaments of, 145
ossification of, 90, 93
Metapophysis (μετα, beyond; *apophysis*), 22
Metatarsal artery, 450
Metatarsus (μετα, behind; ταρσος, the instep), 109
ligaments of, 164
ossification of, 111, 115
Metencephalon (μετα, behind; ἐγκεφαλο the brain), 577

Midriff (Sax. *midd*, middle; *hrif*, the belly), 243
Milk-teeth, 784
Mitral (μιτρα, a mitre) valve, 317
Modiolus (the nave of a wheel), 755, 756
Molar (*mola*, a mill) glands, 780
teeth, 783
eruption of, permanent, 803
temporary, 800
Molecular (*molecula*, dim. of *moles*, a mass) base of chyle, xlix
layer of retina, 728
theory of organisation, xxv
Molecules, histogenetic and histolytic, xxiv
Moles carnea (fleshy mass), 287
Monoplasts (μονος, single; πλασσω, I form), xv
Monro, foramen of, 546
Mons Veneris, 977
Morbid growths, relation to natural tissues, xxvii
Morgagni, corpora or hydatids of, 968
Morphological (μορφη, form; λογος, discourse) anatomy, 1
Morsus diaboli (devil's bite), 991
Motion, ciliary, lix
of protoplasm in cells, xix
Motions of bones in joints, 120
Motorial end-plates of nerves, clvi
stimuli, cxxx, clxii
Mouth, 779
muscles of, 175
Movements of ankle-joint, 160
clavicular, 136
of elbow, 141
foot, 166
hand, 146
hip, 152
knee, 157
lower jaw, 133
occipito-vertebral, 128
of pelvis, 150
radius on ulna, 140
ribs, 131
shoulder, 138
vertebra, 125
wrist and fingers, 146
Muco-albuminous (*mucus; albumen*) substance in fœtus, lxxii
MUCOUS MEMBRANE, General Anatomy of, cxcv
alveoli of, cc
attachment of, cxcvi
basement membrane of, cxcvii
connective tissue of, cxcviii
corium of, cxcvii
divisions of, cxcvi
epithelium of. *See* EPITHELIUM
fibro-vascular layer of, cxcviii
folds and valves of, cxcvi
gastro-pulmonary, cxcvi
genito-urinary, cxcvi
glands of, cc. *See* GLANDS
lymphatics of, cxcviii
MUCOUS MEMBRANE—*continued.*
mammary, cxcvi
muscular tissue of, cxcix
nerves of, cci
papillæ of, cxcix
physical properties of, cxcvii
regeneration of, cci
secretion of, cci
structure of, cxcvii
vessels of, cxcviii
villi of, cxcix
Mucous membrane of intestine, large, 855
small, 842
lachrymal apparatus, 710
larynx, 918
nose, 774
œsophagus, 822
palate, 813
pharynx, 820
rectum, 858
seminal ducts, 974
vesicles, 974
stomach, 834
tongue, 805
trachea, 892
tympanum, 751
ureters, 943
urethra, female, 980
male, 960, 962
urinary bladder, 951
uterus, 985
vagina, 982
vas deferens, 972
vulva, 977, 978
Mucous tissue, lxxvii
Mucus, cci
Müllerian duct, 996
fibres, 728
Multangular bones, 85
Multicuspidate (*multus*, many; *cuspis*, a point) teeth, 783
Multifidus (*multus*, many; *findo*, I cleave) spinæ muscle, 243
Multilocular, ccxxii
Multipolar ganglion-globules, cxl
Muscle-corpuscles, cxxi
juice, reaction of, cxxix
serum, cxxviii
MUSCLES, involuntary, cxv, cxxiv
voluntary, cxv
origin and insertion of, cxv
sheaths of, cxvi
MUSCLES, Descriptive Anatomy of, cxv
abdominal, 248
abductor brevis pollicis, 225
abductor digiti minimi (hand), 227
abductor digiti minimi (foot), 290
abductor indicis, 228
abductor longus pollicis, 223
abductor pollicis (hand), 225
abductor pollicis (foot), 289
accelerator urinæ, 264
accessorii orbicularis, 175
accessorius ad ilio-costalem, 234
adductor brevis, 277

MUSCLES—*continued.*
adductor gracilis, 276
longus, 276
magnus, 277
ossis metacarpi digiti minimi, 227
pollicis manûs, 226
pollicis pedis, 290
anal, 261
anconeus, 215
anconeus brevis, 214
internus, 214
longus, 214
quartus, 215
anomalus, 174
antitragicus, 743
of the arm, 212
arytænoideus obliquus, 917
arytenoid, 917
aryteno-epiglottidean, 917
attollens auriculam, 171
attrahens auriculam, 171
auricular, 170
auricularis, superior, anterior, et posterior, 171
azygos uvulæ, 190
of back, 232
nerves of, 684
basio-glossus, 186
biceps flexor cruris, 270
flexor cubiti, 212
biventer cervicis, 237
brachiæus internus, 214
brachialis anticus, 214
buccinator (trumpeter muscle), 176
bulbo-cavernosus, 264
caninus, 175
cerato-glossus, 186
cervicalis ascendens, 234
chondro-glossus, 186
ciliaris, of orbicularis palpebrarum, 171, 706
ciliary, of eye-ball, 721
circumflexus palati, 191
coccygeus, 263
cochlearis, 764
complexus, 237
compressor hemisphæriûm bulbi, 264
compressor naris, 174
sacculi laryngis, 914
compressores venæ dorsalis penis, 264
constrictor of pharynx, inferior, 188
middle, 188
superior, 189
isthmi faucium, 190
urethræ, 265
coraco-brachialis, 212
corrugator supercilii, 173
cremaster, 251, 965, 1022
crico-arytenoid, lateral, 915
crico-arytenoid, posterior, 914
crico-thyroid, 914
crotaphite, 181
crureus, 276
cucullaris (like a hood), 200

MUSCLES—*continued.*
deltoid, 208
depressor alæ nasi, 174
anguli oris, 176
labii inferioris, 178
detrusor urinæ, 949
diaphragm, 243. *See* DIAPHRAGM.
diaphragma oris, 184
digastric, 183
dilatator naris anterior, 174
naris posterior, 174
pupillæ, 719
of ear, 170, 742, 749
ejaculator seminis, 264
epicranial, 169
erector clitoridis, 266
penis, 264
spinæ, 234
extensor brevis digitorum pedis, 282
carpi radialis brevior, 221
carpi radialis longior, 220
carpi ulnaris, 223
coccygis, 238
digiti minimi, 222
communis digitorum, 221
indicis, 224
longus digitorum pedis, 280
major pollicis, 223
minor pollicis, 223
ossis metacarpi pollicis, 223
primi internodii pollicis, 223
proprius pollicis, 280
secundi internodii pollicis, 223
of eyelids, 171
face, nerves of, 684
femoral, anterior, 273
internal, 276
posterior, 270
flexor accessorius, 287
brevis digiti minimi manûs, 227
brevis digiti minimi pedis, 291
brevis digitorum pedis, 289
brevis pollicis manûs, 226
brevis pollicis pedis, 289
carpi radialis, 216
carpi ulnaris, 217
digitorum profundus, 219
digitorum sublimis, 217
longus digitorum pedis, 286
longus pollicis manûs, 220
longus pollicis pedis, 288
perforans digitorum manûs, 219
perforans digitorum pedis, 286
perforatus digitorum manûs, 217
perforatus digitorum pedis, 289
of foot, 279
of forearm, 215
frontalis, 169
gastrocnemius, 283
gemellus inferior, 269
superior, 269
genio-glossus, 185
genio-hyo-glossus, 185
genio-hyoid, 185
genito-urinary, 263

Muscles—*continued.*
gluteus maximus, 266
medius, 267
minimus, 268
gluteal, 266
gracilis, 276
of great toe, 289
Guthrie's, 265
hamstring, 270
of hand, 225
head, 169
hip, 266
helicis major, 742
minor, 742
Houston's, 264
hyo-glossus, 186
of hyoid bone, 183, 191
of iliac region, 271
iliacus, 271
ilio-aponeurotic, 273
ilio-costalis, 234
ilio-psoas, 271
indicator, 224
infracostal, 243
infraspinatus, 210
intercostal, external, 240
internal, 241
internus mallei, 749
interossei, of hand, 227
of foot, 291
interspinales, 238
intertransversales, 238
ischio-cavernosus, 264
of jaw, 181
kerato-cricoid, 915
of larynx, 914
nerves of, 684
latissimus dorsi, 200
laxator tympani (*major* and *minor*), 750
of leg, anterior, 279
external, 282
posterior, 282
levator anguli oris, 175
anguli scapulæ, 203
ani, 262
glandulæ thyroideæ, 921
labii inferioris, 178
labii superioris, 175
labii superioris alæque nasi, 174
menti, 178
palati, 190
palpebræ, 173, 179, 705
proprius alæ nasi anterior, 174
proprius alæ nasi posterior, 174
prostatæ, 263, 953
levatores costarum, 241
longiores costarum, 242
lingualis, 810
inferior, 810
superficialis, 810
of lips, 175
longissimus dorsi, 235
longus colli, 196
of lower limb, 266

Muscles—*continued.*
of lower limb, nerves of, 686
lumbricales (worm-shaped muscles), 219, 287
masseter (masticating muscle), 181
mastoido-humeral, 193
of mouth, 175
multifidus spinæ, 238
mylo-hyoid, 184
naso-labialis, 174
of neck, flexor, 183
of nose, 173
noto-glossus (νωτος, a back; muscle of the upper surface or dorsum of the tongue), 810
oblique, of abdomen, external, 248
internal, 250
of the ear, 743
of eye, action of, 501*
inferior, 180
superior, 179
obliquus capitis inferior, 239
superior, 239
obturator externus, 269
internus, 269
occipitalis, 169
occipito-frontalis, 169
omo-hyoid, 192
opponens digiti minimi, 227
pollicis, 225
orbicularis latus, 171
orbicularis oris, 175
palpebrarum, 171, 706
of orbit, 179
action of, 180, 501*
nerves of, 684
of palate, 187
nerves of, 684
palato-glossus, 190
palato-pharyngeus, 190
palmaris brevis, 225
longus, 217
pectineus, 276
pectoralis major, 203
minor, 206
of penis, 264
of perinæum, 261
peroneus brevis, 282
longus, 282
tertius, 281
perpendicularis externus of tongue, 811
of pharynx, 187
nerves of, 684
plantar, short, 289
plantaris, 285
platysma myoides, 178
popliteus, 285
pronator quadratus, 220
radii teres, 215
psoas magnus, 272
parvus, 273
pterygoid external, 182
internal, 181
pyramidalis abdominis, 255

MUSCLES—*continued.*
pyramidalis nasi, 174
pyriformis, 268
quadratus femoris, 269
lumborum, 255
menti, 178
quadriceps extensor cruris, 274
recti of eye, 179
rectus abdominis, 243
capitis anticus major, 196
capitis anticus minor, 196
capitis lateralis, 196
capitis posticus major, 239
capitis posticus minor, 239
femoris, 274
rectus sternalis, 243
retrahens auriculam, 171
rhomboideus major, 203
minor, 202
of ribs, 240
risorius (laughing muscle), 176
rotatores spinæ, 238
sacci lachrymalis, 173
sacro-coccygeus posticus, 238
sacro-lumbalis, 234
salpingo-pharyngeus, 189
Santorini's, 176
sartorius (tailor's muscle), 273
scalenus anticus, 193
medius, 195
posticus, 195
scapular, 208
semimembranosus, 271
semispinalis colli, 237
dorsi, 238
semitendinosus, 271
serratus magnus, 207
posticus inferior, 233
posticus superior, 233
of shoulder, 208
soleus (muscle like a sole), 284
sphincter ani, external, 262, 265
internal, 261
oris, 175
of pupil, 719
vaginæ, 266
sphincter vesicæ, 949
spinalis cervicis, 238
dorsi, 235
splenius, 234
capitis, 234
colli, 234
stapedius, 750
sternalis brutorum, 243
sterno-cleido-mastoid, 193
sterno-hyoid, 191
sterno-thyroid, 191
stylo-glossus, 186
stylo-hyoid, 184
stylo-hyoideus alter, 184
stylo-pharyngeus, 189
subanconeus, 215
subclavius, 206
subcostal, 243
subcrureus, 276

MUSCLES—*continued.*
submaxillary, 183
subscapularis, 208
supinator radii brevis, 223
longus, 220
supraspinatus, 208
temporal, 181
tensor palati, 191
tarsi, 173
tympani, 749
vaginæ femoris, 273
teres major, 211
minor, 211
of thigh, 266
thorax, 240
nerves of, 685
thyro-arytenoid, 916
thyro-epiglottidean, 917
thyro-hyoid, 192
tibialis anticus, 279
posticus, 288
of tongue, extrinsic, 185
intrinsic, 810
trachelo-mastoid, 235
tragicus, 743
transversalis abdominis, 253
cervicis, 235
transversus auriculæ, 743
pedis, 290
perinæi, 264, 265
trapezius, 200
triangularis oris, 176
sterni, 243
triceps extensor cubiti, 214
trochlearis (trochlea, a pulley), 179
of tympanum, 749
upper limb, 198
nerves of, 685
of urethra, 264
vastus externus, 275
internus, 276
Wilson's, 265
zygomaticus major, 176
minor, 176
Muscular contractility or irritability, cxxix
duration of, after death, cxxx
stimuli of, cxxx
current, cxxix
rigidity, cxxxi
sense, cxxix
MUSCULAR TISSUE, General Anatomy of, cxv
blood-vessels of, cxxiii
chemical composition of, cxxviii
cleavage into disks, cxx
connection with tendons, cxxi
corpuscles of, cxxi
cross stripes of, cxvii, cxix
development of, cxxvi
fasciculi of, cxvi, cxvii
fibres of, striped, cxvii
branched, cxxi
length and ending of, cxxi
unstriped, cxxiv

MUSCULAR TISSUE—*continued.*
fibrils of, cxviii
growth of, cxxvii
interstitial granules of, cxx
involuntary, cxxiv
lacerti of, cxvi
lymphatics of, cxxiii
myolemma of, cxviii
nerves of, cxxiv
terminations of in, clvi
nuclei of, cxxi
physical properties of, cxxix
plain or unstriped, cxxiv
regeneration of, cxxviii
sarcolemma of, cxviii
sarcous elements of, cxix
sensibility of, cxxix
sheath of, cxvi
vital properties of, cxxix
voluntary, or striped, cxv
Muscular tissue, of arteries, clxx
cremasteric, 965
of choroid, 721
dartos, 964
Fallopian tubes, 992
hair-follicles, ccxi
heart, cxxvi, 316
intestine, large, 853
small, 841
iris, 719
larynx, 914
lymphatics, clxxxiv
mammary glands, 1004
mucous membrane, cxcix
nipples, 1002
œsophagus, 821
pharynx, 820
prostate, 954
rectum, 858
seminal ducts, 974
vesicles, 974
skin, cciii
stomach, 832
sweat-ducts, ccxvi
tongue, 809
trachea, 891
urinary bladder, 948
uterus, 985
vagina, 982
vas deferens, 972
veins, clxxiii
Musculi papillares of heart, 305, 307
left ventricle, 313
right ventricle, 308
pectinati of heart, 304
left auricle, 312
right auricle, 308
Musculo-cutaneous nerves, 648, 652, 680
Musculo-intestinal layer in embryo, 859
Musculo-phrenic (*musculus*, muscle; φρην, the diaphragm) artery, 375
Myentericus (μυς, a muscle; ἐντερον, an intestine) plexus, 851
Mylo-hyoid (μυλη, a mill, the jaw; *hyoid* bone) artery, 356
Mylo-hyoid groove, 52
nerve, 606
ridge, 51
Myoides (μυς, a muscle; εἰδος, shape). *See* PLATYSMA
Myolemma (μυς, a muscle; λεμμα, a husk, or rind), cxviii
Myology (μυς, a muscle; λογος, discourse), 167
Myosin (μυς, a muscle), cxxviii
Myotome (μυς, a muscle; τεμνω, I divide), 1
Myrtiform (μυρτον, a myrtle-berry; *forma*, shape) fossa, 45

NAILS, ccvi
development of, ccviii
growth of, ccvii
matrix of, ccvi
reproduction of, ccviii
structure of, ccvii
Nares (nostrils), anterior, 61
mucous membrane of, 775
posterior, 59
septum of, 61
Nasal (*nasus*, the nose) bone, 49
ossification of, 70, 71
cartilages, 771
duct, 709, 710
fossæ, or cavities, 61, 773
mucous membrane of, 774
openings into, 64, 774
walls of, 63
Nasmyth's membrane, 791
Nates (buttocks) in cerebrum, 554
National differences in skull, 72
Navicular (*navicula*, a small ship or boat) bone of foot, 108
of hand, 84
Neck, dissection of, 1052, 1053
fasciæ of, 196
muscles of, 193, 234—240
veins of, 455
Negro, cause of colour in skin of, lxiv
NERVES, CEREBRO-SPINAL, General Anatomy of, cxliv
afferent, cxxxii
branching and conjunction of, cxlv
cellular sheath of, cxliv
communication with sympathetic, clix
compound, clxiii
connection with cells, cxlviii
nervous centre, clxxxviii
ganglia, clxxxiii
grey matter, cxlvii
development of, cxliii
differences of, clvii
division of, cxlix
efferent, cxxxii
fibres of, cxlv
functions of, ix, clxii
funiculi of, cxliv, cxlviii
ganglia at roots of, cxlix

NERVES, CEREBRO-SPINAL—*continued.*
motor, cxliii
moto-sensory, clxiii
nerves of, cxlvi
neurilemma of, cxliv
origins of, cxlvii, 583, 511
apparent, cxlvii
real or deep, cxlvii
peculiarities of, cxlix
perineurium of, cxliv
plexuses of, cxlvi
course of fibres in, cxlvi
regeneration and reunion of, clxv
relation of sympathetic to, clix
roots of, cxlvi
sensory, clxiii
terminations of, cl
sheath of, cxlv
simple, clxiii
structure of, cxliv
terminations of, cxlix
in end-bulbs, cli
epithelium, clvi
glands, clvi
hair-follicles, clv
muscle, clvi
networks or terminal plexuses, cl
nose, clv
organs of special sense, clv
Pacinian bodies, clii
teeth, clv
touch-bodies, cli
vessels of, cxlv
vital properties of, clxii
NERVES, SYMPATHETIC, General Anatomy of, clviii
fibres of, clviii
parts of, clviii
relation to cerebro-spinal nerves, clix
relation to roots of spinal nerves, clxi
structure of, clviii
NERVES, Descriptive Anatomy of, 582
abdominal of ilio-hypogastric, 660
abducent, 586, 589, 610
accessory, spinal, 625
obturator, 663
acromial, 640
of arachnoid, 566
of arm, 683
articular, of shoulder-joint, 644, 646
of elbow-joint, 649
hip-joint, 662, 664, 675
knee, 663, 665, 676, 679
temporo-maxillary joint, 606
wrist, 649
auditory, 587, 589, 615, 758, 763
auricular, of auriculo-temporal, 606
great, 638
posterior, 612
of pneumogastric, 621
of small occipital, 638
auriculo-temporal, 606
NERVES—*continued.*
axillary, 645
buccal, 606
of facial, 614
of buttock, 683
cardiac, lower, 693
middle, or deep, 692
of pneumogastric, 623
upper, 690
carotid of petrous ganglion, 617
of Vidian, 605
cavernous, of penis, 703
cerebro-spinal, 582
cervical, divisions of, anterior, 636
posterior, 633
second, 636
superficial, 638
cervico-facial, 613
chorda tympani, 611
ciliary, long, 599
short, 600
circumflex of arm, 645
coccygeal, divisions of, anterior, 668
posterior, 635
of Cotunnius, 604
cranial, 582
crural, anterior, 664
internal, 662
cutaneous, of head, 682
of lower limb, 683
trunk, 682
upper limb, 683
abdominal, 657
external, of arm, 648
musculo-spiral, 653
internal, of arm, 646
musculo-spiral, 652
peroneal, 680
of thigh, 665
lateral, of last dorsal, 658
middle, of thigh, 665
of obturator, 662
thoracic, anterior, 657
lateral, 657
dental, anterior, 601
inferior, 608
posterior, 601
descendens noni, 626
diaphragmatic, 640
digastric, 613
digital, in foot, 678, 679, 681
in hand, 649, 651, 653
dorsal, divisions of, anterior, 655
posterior, 624
first, 655
of foot, 681, 683
hand, 649, 653, 683
last, 658
of penis, 671
dorsi-lumbar, 658
of dura mater, 564
facial, 587, 589, 610
of femoral artery, 664
frontal, 597
gastric, 623

NERVES—*continued.*
genito-crural, 660
glosso-pharyngeal, 519, 587, 589, 615
gluteal, inferior, 673
superior, 667
gustatory, 606
hæmorrhoidal, inferior, 672, 703
superior, 703
hepatic, 701
hypogastric, 660
hypoglossal, 519, 587, 589, 626
iliac, 660
ilio-hypogastric, 660
inguinal, 660
incisor, 608
infra-maxillary, 615
orbital, 602
of facial, 613
trochlear, 599
intercostal, first, 655
lower or abdominal, 657
upper or pectoral, 655
intercosto-humeral, 657
interosseous anterior, 651
posterior, 654
Jacobson's, 617
labial, 606
lachrymal, 597
of Lancisi, 542
laryngeal, 622
of leg, 683
lingual, of fifth, 608
glosso-pharyngeal, 618
of lower limb, 683, 686
lumbar, divisions of, posterior, 634
anterior, 658
fifth, 667
lumbo-sacral, 669
malar, of facial, 613
of orbital, 600
masseteric, 605
mastoid, 638
maxillary, inferior, 596, 605
superior, 596, 600
median, 649
mental, 608
motor of eye, common, 586, 589, 593
external, 586, 589
musculo-cutaneous, of arm, 648
leg, 680
spiral, 652
mylo-hyoid, 606
nasal, 598
upper, 603
of Vidian nerve, 604
naso-palatine, 604
obturator, 662
accessory, 663
occipital (of facial), 612
great, 634
small, 638
oculo-nasal, 598
œsophageal, 623
olfactory, 583, 589, 592
ophthalmic, 596, 597

NERVES—*continued.*
optic, 580, 589, 592
orbital, 600
ovarian, 704
palatine, anterior or larger, 603
external, 603
posterior or smaller, 603
palmar, cutaneous, 649, 651, 683
palpebral, 543, 550
parotid, 606
pathetic, 586, 589, 594
of penis, 683
of perineum, 683
perineal, 670
peroneal, 679, 680
communicating, 680
petrosal, superficial, large, 605
external, 611
small, 617
pharyngeal of pneumo-gastric, 621
of glosso-pharyngeal, 617
of spheno-palatine ganglion, 605
of sympathetic, 690
phrenic, 640
of pia mater, 564
plantar, external, 679
internal, 677
pneumo-gastric, 519, 587, 589, 618
lobule of, 524
popliteal, external, 679
internal, 676
portio dura, 587, 610
mollis, 587, 615
pterygoid, external, 606
internal, 606
pudendal, inferior, 675
pudic, 670
pulmonary, of pneumogastric, 623
radial, 653
recurrent laryngeal, 622
renal, 701
respiratory, external, 644
sacral, divisions of, anterior, 668
posterior, 635
fifth, 668
fourth, 668
saphenous, long, or internal, 666
short, or external, 677
sciatic, great, 675
small, 673
scrotal, long, 670
spermatic, external, 661
spheno-palatine, 603
spinal, 628. *See* SPINAL NERVES.
accessory, 519, 587, 589, 625
splanchnic, great, 695
small, 696
smallest, 696
sternal, 640
stylo-hyoid, 613
suboccipital, 632, 636
subscapular, 645
supra-clavicular, 639
maxillary, 615
orbital, 598

NERVES—*continued.*
supra-scapular, 644
trochlear, 597
temporal, of auriculo-temporal, 606
deep, 605
of facial, 613
of temporo-malar, 600
temporo-facial, 613
malar, 600
of thigh, 683
thoracic, anterior, 645
posterior, 644
thyroid, 692
tibial, anterior, 682
posterior, 677
tonsillitic, 618
trifacial or trigeminal, 586, 589, 595
trochlear, 586, 589, 594
of trunk, 682, 684
tympanic, 617
of tympanum, 54
ulnar, 648
collateral, 652
of upper limb, 683, 685
of uterus, 704
vaginal, 704
of vas deferens, 703
vesiculæ seminales, 703
vestibular, 66, 67
Vidian, 604, 690
of Wrisberg, 646
NERVES, SYMPATHETIC, Descriptive Anatomy of, 686
ganglia of. *See* GANGLION
gangliated cords of, 686
cervical part, 688
lumbar part, 696
sacral part, 696
thoracic part, 693
plexuses of, 698. *See* PLEXUSES
NERVES of areolar tissue, lxxiv
of arteries, clxxi
auditory canal, 744
bone, cii
choroid coat of eye, 724
in cochlea, 763
of conjunctiva, 708
cornea, 716
coverings of testis and cord, 967
Fallopian tubes, 992
fibrous tissue, lxxvi
heart, 321
intestine, small, 850
large, 856
iris, 724
kidney, 938
larynx, 919
liver, 867
lungs, 903
mammary gland, 1004
mucous membrane, cci
muscle, cxxiv
nose, 776
NERVES—*continued.*
of ovaries, 992
pancreas, 883
parotid gland, 816
penis, 959
pinna, 743
pleura, 894
prostate gland, 954
rectum, 858
secreting glands, ccxxv
in semicircular canals, 758
of serous membranes, cxciii
spleen, 887
stomach, 837
sublingual gland, 818
submaxillary gland, 817
suprarenal bodies, 941
teeth, 805
testis, 975
thymus gland, 925
thyroid body, 922
tongue, 812
tonsils, 814
trachea, 892
tympanum, 752, 753
ureters, 943
urethra, female, 980
urinary bladder, 951
uterus, 987
vagina, 982
veins, clxxiv
vulva, 980
NERVE-CELLS, or vesicles, cxxxix
of cerebellum, 528
cerebro-spinal centre, cxli
cerebrum, 560, 561
development of, clxiv
of ganglia, cxlii
olfactory, clv
of retina, 728
spinal cord, 510
varieties of, cxl
Nerve-corpuscles, genital, cli
Nerve-eminence, clvii
NERVE-FIBRES, cxxxv
afferent, cxxxii
axis of, cxxxvii
of cerebro-spinal nerves, cxliv
gelatinous or grey, cxxxviii
distribution in different nerves, clvii
in terminations of nerves, cxlix, cl, cli, clv, clvi
in sympathetic nerve, clviii
medullated, cxxxv
non-medullated, cxxxv, cxxxviii
white, appearance of, cxxxv
axis cylinder of, cxxxvii
in cerebellum, 529
in cerebro-spinal nerves, cxliv
in cerebrum, 555
connection with grey matter, cxlvii
ganglion-cells, cxlii
development of, clxiv

NERVE-FIBRES—*continued.*
white, distribution in different nerves, clvii
efferent, clxii
in ganglia, cxlii
looped, cxlvi
in medulla oblongata, 518
medullary sheath of, cxxxvi
membranous tube of, cxxxvi
in plexuses, cxlvi
in pons Varolii, 521
primitive band of, cxxxvi
sheath of, cxxxvi
of retina, 728
roots of spinal nerves, 511
spinal cord, 509
in sympathetic nerve, clviii
terminations of. *See* NERVES, CEREBRO-SPINAL, terminations of
varicose, cxxxvii
white substance of, cxxxvi
Nervi molles, 692
nervorum (nerves of nerves), clxvi
NERVOUS SUBSTANCE, cxxxiii
cells, corpuscles, or vesicles of. *See* NERVE-CELLS
of cerebellum, 527
microscopic structure, 528
of cerebro-spinal nerves. *See* NERVES, CEREBRO-SPINAL
of cerebrum, grey, 559
white, 555
chemical composition of, cxxxiii
fibres of. *See* NERVE-FIBRES
ganglia of. *See* GANGLIA
of medulla oblongata, grey, 519
white, 518
of retina, 726
of spinal cord, grey, 509
white,
structural elements of, cxxxiv
of sympathetic, clviii
NERVOUS SYSTEM, General Anatomy of, cxxxi
cerebro-spinal centre of, cxxxii
nerves of, clxxxv
divisions or parts of, cxxxii
functions of, cxxxi
ganglia of, cxxxii
sympathetic portion of, clviii
vital properties of, clxii
NERVOUS SYSTEM, Descriptive Anatomy of, 501
cerebro-spinal axis, 501
cranial nerves, 582
spinal nerves, 628
sympathetic nerves, 686
Nervus abducens, 586, 610
cardiacus magnus, 692
cardiacus profundus, 692
cardiacus superficialis, 690
cruralis internus, 676
ischiadicus, 675
ischiadicus minor, 673

Nervus—*continued.*
motor oculi externus, 586
motorius oculi, 593
oculo-nasalis, 598
patheticus, 586, 594
perforans Casserii, 648
popliteus internus, 676
renalis posterior, 696
splanchnicus supremus, 696
tibialis posterior, 676
trigeminus, 586, 595
trochlearis, 586, 594
vagus (wandering nerve), 587, 618
Neural (νευρον, a nerve) cavity, 3
spines of vertebræ, 22
Neurapophysis (νευρον, a nerve; *apophysis*), 22
Neurilemma (νευρον, a nerve; λεμμα, a peel or skin), cxliv
peculiarities of, cxlix
of spinal cord, 564
Neuroglia (νευρον, a nerve; γλια, glue), cxli, 543
Neurology (νευρον, a nerve, λογος, discourse), 501
Neurotome (νευρον, a nerve; τεμνω, I cut), l
Nipple, 1002
Nitrogenous and non-nitrogenous substances, v, vi
Nodule (*nodulus*, from *nodus*, a knot) of cerebellum, 525
Nodulus Arantii, 308
Nodus encephali, 521
Norma verticalis (vertical rule), 73
NOSE, 771
alæ of, 772
cartilages of, 771
cavities of, 61, 773
constituent parts of, 771
development of, 778
fossæ of, 61, 773
glands of, 775
meatus of, 43
mucous membrane of, 774
muscles of, 173
nerves of, 599, 603, 604, 776
olfactory region of, 776
septum of, 61, 772
skin of, 771
vessels of, 350, 356, 361, 362, 456, 464, 778
Notch, of acetabulum, 96
interclavicular, 24
jugular, 31
sacro-sciatic, great and small, 96
scapular, 76
sigmoid, 52
supraorbital, 34
suprascapular, 76
Notches of vertebræ, 4
Notochord (νωτος, the back; χορδα, a string or chord), 16
Notoglossus (νωτος, a back; γλωσσα, a tongue) muscle, 810

Nuck, canal of, 965, 987
congenital hernia in, 1026
Nuclear (*nucleus*) fibres, lxxi
layer of retina, 727
Nuclei (*nucleus*, a kernel) of blood-corpuscles, xxix, li
of cartilage-cells, lxxxi
of colourless blood-corpuscles, xxxii
of connective tissue-corpuscles, lxxiii
division of, xvi
of epithelial cells, liii
of fat cells, lxiii
free, xv
of grey matter in medulla oblongata, 519
multiplication of, xviii
in muscle, cxxi, cxxiv
of ossification, cxiv
part of, in nutrition, xxiii
of pigment-cells, lxiv
Nucleolus (dim. of *nucleus*), xiii
Nucleus (kernel) of cells, xiii
olivary, 515
tæniæformis (tape-shaped nucleus), 561
Nutrition of textures, xxiv
relation to secretion, ccxix
Nymphæ, 977
development of, 1001

OBTURATOR (*obturo*, I stop up) artery, 423
fascia, 261
foramen, 93, 96
ligament or membrane, 150
muscles, 269
nerve, 662
accessory, 663
Occipital (*occiput*, the back of the head) artery, 351
bone, 29
ossification of, 67, 70
fissure, 536
foramen, 29, 61
fossæ, 31
nerves. *See* NERVES
protuberances, 30, 31
ridge, 30
sinus, 463, 464
Occipito-atlantal ligament, 128
Occipito-axial ligament, 128
Occipito-frontal aponeurosis, 169
Occipito-frontalis muscle, 169
Occipito-mastoid suture, 55
Occipito-parietal suture, 54
Odontoid (ὀδους, stem; ὀδοντ, a tooth; εἰδος, shape) ligament, 126
process of the axis, 9, 21
Odoriferous matters in blood, xli
Œsophageal arteries. *See* ARTERY
glands, 823
nerves, 623
plexus, 695
Œsophagus (οἰω or οἰσω, obs. = φερω, I bear; φαγειν, to eat), 821
coats of, 821
Œsophagus, development of, 860
dilatations of, 823
foramen for, in diaphragm, 246
Olecranon (ὠλενη, the elbow; κρανος, a helmet), 82
Olein (*oleum*, oil), lxvii, cxxxiv.
Olfactory bulb, 584
cells, clv, 776
nerve. *See* NERVES
membranes of, cxlix
Olivary (*oliva*, an olive) bodies, 515
development of, 577
fasciculus, 519
nucleus, 521
Omenta, 824, 826
Omentum (the caul) gastro-colic, 829
gastro-hepatic, 827
gastro-splenic, 829
great, 829
sac of, 827
small, 827
Omo-hyoid (ὠμος, the shoulder; *hyoid*, bone) muscle, 192
Omphalo-enteric (ὀμφαλος, navel; ἐντερον, intestine) canal, 859
Opercula (coverings, or lids) of dental follicles, 794, 801
Ophthalmic (ὀφθαλμος, an eye) artery. *See* ARTERY.
ganglion, 599
nerve, 597
vein, 464
Opposition, 120
Optic nerve, 592. *See* NERVES
fibres of, clvii
membranes of, cxlix
tract, 584
Ora serrata (serrated border), 725
Orbicular bone, 749
ligament, 138
Orbicularis muscles. *See* MUSCLES
Orbital arch, 34
foramina, 34, 57
Orbits (*orbita*, a circle), 56
dissection of, 1056
muscles of, 179
nerves passing into, 594
Organ of Corti, 760, 761
structure of, 764
enamel, 797
of Giraldès, 973, 1001
of Rosenmüller, 992
Organic systems of Bichat, iii
Organizing force, vii
Organon adamantinæ, 797
Organs and textures, i
ORGANS of circulation, 297
development of, 323
of digestion, 779, 823
generation, female, 977
male, 952
development of, 995
mastication and deglutition, 779
respiration, 888
development of, 904

ORGANS—*continued.*
of senses, 705
urinary, 926
development of, 992
voice, 905
Orthognathous (ὀρθος, upright; γναθος, a jaw) skulls, 73
Os calcis, 107
development of, 111, 115
capitatum, 85
coxæ (the bone of the hip), 693
lenticulare, 749
linguæ, 52
magnum, 85
development of, 93
multangulum majus, 85
multangulum minus, 85
orbiculare, 749
pectinis, 95
pectoris, 23
planum, 43
pubis, 95
rotundum, 85
tincæ (tench's mouth), 983
unguis, 50
uteri externum, 983
uteri internum, 984
xiphoides, 23
Ossa triquetra (triangular bones), 85
Ossa Wormiana, 85
Ossicula auditûs, 748
development of, 66
Ossification, cii
in cartilage, cvi
of cranial bones, 67
intracartilaginous, ciii, cvi
intramembranous, ciii
of lower limb, 110
nuclei of, cxiv
of ribs and sternum, 28
of upper limb, 89
of vertebræ, 18
Ossified cartilage, xcix
Osteoblasts (ὀστεον, a bone; βλαστος, a germ), cv
Osteodentine (ὀστεον, a bone; *dens*, a tooth), 792
Osteogen (ὀστεον, a bone; γενναω, I produce), cv, cix
Osteology (ὀστεον, a bone; λογος, discourse), 2
Ostium abdominale of Fallopian tube, 991
uterinum of Fallopian tube, 992
uteri, 984
Otic (οὖς, gen. ὠτος, the ear) ganglion, 608, 1057
Otoconia (οὖς, gen. ὠτος, an ear; κονις, dust), 757
Otoliths (οὖς, gen. ὠτος, an ear; λιθος, a stone), 757
Ovarian artery. *See* ARTERY
nerve, 704
OVARIES (*ovum*, an egg), 988
development of, 995
Graafian vesicles of, 989

Ovaries—*continued.*
ligaments of, 986
nerves of, 704, 992
situation of, 825
structure of, 988
vessels of, 992
Ovicapsule, 990
Oviducts, 991
Ovula Nabothi, 985
Ovum, 989
development of, 990
production of cells in, xv, xvii
structure of, 990
Owen's nomenclature of vertebral elements, 22

PACCHIONI glandulæ, 567
Pacinian bodies, clii
discovery of, clii
distribution of, cliii
end of nerve-fibres in, clvi
function of, clv
in skin, ccvi
structure of, cliii
Palate, 813
bone, 46
ossification of, 70, 71
dissection of, 1058
hard, 44, 46, 813
muscles of, 187
soft, 189, 813
Palatine arteries. *See* ARTERY
canal, 45, 47
foramen, 45, 47
glands, 813
nerves. *See* NERVES
Palato-glossus muscle, 190
Palato-pharyngeus muscle, 190
Palmæ plicatæ 984
Palmar arches, 393, 400
ligaments, 143
Palmaris muscles, 217, 225
Palpebræ (*palpebra*, an eyelid), 705
Palpebral artery, 362
Pampiniform (*pampinus*, a tendril; *forma*, shape) plexus, 975
Pancreas (παν, all; κρεας, flesh), 881
development of, 861, 883
dissection of, 1073
duct of, 883
head and tail of, 881
lesser, 881
position of, 826, 881
secretion of, 883
structure of, 882
varieties of, 883
vessels and nerves of, 883
weight of, 882
Pancreatic artery, 409
duct, 882
juice, 883
plexus, 702
Pancreatico-duodenal arteries, 408, 410
Pancreatin, 883

Panniculus adiposus, lxv, cciii, 168
 carnosus, 168, 179
Papilla lachrymalis, 705, 709
Papillæ of conjunctiva, 708
 dental, 793
 of hair-follicles, ccxi
  kidney, 928, 929
  mucous membrane, cxcix
 œsophageal, 823
 of skin, cciv
 of tongue, 806
  circumvallate or large, 806
  conical, 807
  filiform, 807
  fungiform or middle-sized, 807
  structure of, 808
Papillary stage of dentition, 793
Par trigeminum, 586
 vagum, 587
Parapophysis (παρα, beside; *apophysis*), 22
Parenchyma (παρεγχυμα, interstitial infusion) of glands, ccxxv
 of liver, reaction of, 863
Parenchymal tissue, lxx
Parietal bone, 32
  ossification of, 67, 70
 suture, 55
Parieto-mastoid suture, 55
PAROTID GLAND (παρα, near; οὖς, gen. ὠτος, the ear), 814
 accessory, 815
 duct of, 816
 structure of, c 816
 vessels and nerves of, 816
Parotid fascia, 197
Parovarium (παρα, near; *ovarium*, ovary), 992
 origin of, 998
Pars ciliaris retinæ, 725
 intermedia of vestibule, 979
Patella (a dish or plate), 103
 ligaments of, 155
 ossification of, 115, 116
Patellar (*patella*) plexus, 667
Pavement epithelium, liii
Pectineal (*pecten*, a name of the pubic bone) line, 96
Pectineus muscle, 276
Pectoral region, dissection of, 1061
Pectoralis muscle, 203, 206
Pedicle of vertebræ, 4
Peduncles of cerebellum, 522, 557
  development of, 577
 of cerebrum, 536
  development of, 578
 of corpus callosum, 539, 542
 of pineal gland, 552
Pelvic fascia, 260
 plexus, 703
Pelvis (a basin), 93, 97
 articulations of 147
 axis of, 99
 brim of, 97
 compared with shoulder, 116
Pelvis—*continued.*
 development of, 111, 112
 differences in the sexes, 100
 dimensions of, 100
 dissection of, 1076
 fasciæ of, 260
 lower or true, 97
 position of, 98
 upper or false, 97
 of kidney, 928
Penis, 955
 corpora cavernosa of, 956
 corpus spongiosum of, 958
 development of, 1001
 glans of, 955
 helicine arteries of, 958, 959
 integument of, 955
 ligament, suspensory, of, 955
 muscles of, 264
 nerves of, 671, 703, 956, 959
 prepuce of, 955
 vessels of, 428, 956, 958, 959
Penniform (*penna*, a feather; *forma*, shape) muscles, cxvii
Pepsin (πεπτω, I digest), v
Peptic (πεπτω, I digest) glands, 837
Perforans muscle, in hand, 219
 in foot, 286
Perforated space, anterior, 539
 posterior, 536
Perforatus muscle, of hand, 217
 of foot, 289
Pericardiac arteries, 374, 402
Pericardium (περι, about; καρδια, the heart), 300
 dissection of, 1067
 vestigial fold of, 300
Perichondrium (περι, about; χονδρος, cartilage), lxxxi
Pericranium (περι, about; κρανιον, the skull), 169
Perilymph (περι, about; *lympha*, water), 753, 757
Perimysium (περι, around; μυς, a muscle), cxvi
Perinæum (περι, about; ναιω, I am situated), blood-vessels of, in relation to lithotomy, 1046
 development of, 1001
 dissection of, 1037, 1069
 fascia of, 259, 1039
 muscles of, 261
 raphe of, 1038
Perineal arteries, 426, 427, 428
 fascia, 259, 1040
 nerve, 670
Perineurium (περι, about; νευρον, a nerve), cxliv
Periodontal (περι, about; ὀδους, a tooth) surface of teeth, 791
Periosteum (περι, about; ὀστεον, a bone), lxxxvii, c
Peristaltic (περιστελλω, I constrict or narrow) movement of the intestines, 841

PERITONEUM (περι, about; τεινω, I stretch), 826
continuity of, traced, 827
dissection of, 1072
at groin, 1024
folds of, 826
fossæ or pouches of, 1024
ligaments formed by, 827
mesenteries of, 826
omenta of, 827, 828
parietal and visceral portions, 826
smaller cavity of, 827
structure of, 826
Perivascular canals, clxxxiii
Peroneal (περονη, the pin of a buckle, the fibula) arteries, 444, 445
bone, 105
nerve, 679, 680
Peronei muscles, 281, 282
Peroneo-tibial articulation, 158
Pes anserinus (goose's foot), 611
accessorius, 544
hippocampi, 544
Petit, canal of, 736
Petrosal artery, 752
nerves, 605
sinus, 463
Petrous (πετρα, a rock) ganglion, 616
portion of the temporal bone, 37
Peyer's glands, 841, 846
Phalanges (φαλαγξ, a rank of soldiers) of fingers, 87
articulations of, 145
ossification of, 90, 93
of toes, 110
articulations of, 166
ossification of, 111, 115
Pharyngeal artery, 357
nerves. *See* NERVES
plexus, 617, 622, 690
PHARYNX (φαρυγξ), 187, 819
dissection of, 1058
glands of, 820
mucous membrane of, 820
muscles of, 187
Phrenic (φρην, the diaphragm) arteries, 374, 416
centre, 245
nerve, 640
Pia mater, 564
development of, 582
Pigment, lxiii
chemical composition of, lxiv
of choroid, 718
iris, 719
use of, lxv
Pigment-cells, movements in, xx
Pillars of abdominal ring, 250, 1019
fauces, 189
fornix, 545
iris, 716
Pineal gland, 552
development of, 579, 580
Pinna (a feather), 740
cartilage of, 741
Pinna—*continued.*
ligaments of, 742
muscles of, 170, 742
nerves and vessels of, 743
Pisiform (*pisum*, a pea; *forma*, shape) bone, 85
articulations of, 144
Pit of stomach, 831
Pith of hair, ccviii
Pituitary (*pituita*, phlegm or mucus) body, 539
fossa, 39
membrane of nose, 774
Plantar (*planta*, the sole of the foot) arteries) 446, 447
fascia, 296
ligaments, 161-166
nerves, 677. *See* NERVES.
Plantaris muscle, 285
Planum temporale (temporal plane), 32
Plasma (πλασσω, I form) of blood, xxvii, xxxii
salts in, xli
of chyle, xlix
of lymph, xlviii
Plastic (πλασσω, I form) force, viii
Plate, central, of ethmoid, 42
mesial, of embryo, 859
of vomer, 48
orbital of frontal bone, 33
of ethmoid, 43
palate, of palate bone, 46
of superior maxilla, 44
tympanic, 37
of vertebra, 4
vertical, of palate, 47
Plates, visceral, of embryo, 859
Platysma myoides (πλατυσμα, a plate, from πλατυνω, I extend; μυς, a muscle; εἶδος, shape), 178
Pleura (πλευρα, a rib or side) costalis, 893
pulmonalis, 893
Pleuræ, 892
dissection of, 1066
mediastinum or partition of, 893
nerves of, 894
structure of, 894
Pleurapophysis (πλευρα, a side; *apophysis*), 22
Pleuro-peritoneal cavity, 859
Plexiform origin of lymphatics, clxxxii
PLEXUSES of nerves, cxlvi
in muscle, clvi
aortic, 702
brachial, 641
branches of, 643
cardiac, 690, 698
carotid, 689
cavernous, 689, 690
cervical, 636
branches of, 638
posterior, 634
cœliac, 701

PLEXUSES—*continued.*
coronary, anterior, 699
posterior, 699
of the stomach, 701
cranial, 688
cystic, 702
diaphragmatic, 699
epigastric, 699
gangliosus, 703
gastro-duodenal, 702
epiploic, 702
left, 702
hepatic, 701
hypogastric, 702
infraorbital, 602
intermesenteric, 702
inferior, 702
lumbar, 658
branches of, 659
myentericus (musculo-intestinal plexus), 851
œsophageal, 623
pancreatic, 702
patellar, 667
pelvic, 703
pharyngeal, 617, 622, 690
preaortic, 695, 698
prevertebral, 687
prostatic, 703
pulmonary, anterior, 623
posterior, 623
pyloric, 702
renal, 701
sacral, 669
solar, 699
spermatic, 701
suprarenal, 699
tonsillar, 618
tympanic, 617, 752
vaginal, 704
vesical, 703
Plexuses of absorbent vessels, clxxxii
interlaminar, 850
PLEXUSES of veins, choroid, 460, 548
of fourth ventricle, 526
of lateral ventricle, 543
of third ventricle, 548
hæmorrhoidal, 479
ovarian, 474
pampiniform, 474, 975
prostatic, 479
pterygoid, 457
spermatic, 474
subperitoneal arterial, 418
uterine, 479
vaginal, 479, 982
vertebral, 471
vesical, 478
Plica gubernatrix (guiding fold), 1000
semilunaris (semilunar fold), 705
Plis de passage (connecting convolutions of brain), 536
Pneumogastric (πνευμων, the lung; γαστηρ, the stomach) nerve. *See* NERVES
Pomum Adami (Adam's apple), 906
Pons Tarini (bridge of Tarin), 537
Pons Varolii (bridge of Varolius), 514, 521
Popliteal (*poples*, the ham) space, dissection of, 1079
Popliteal artery. *See* ARTERY
Popliteus muscle, 285
Porta (gate), or portal fissure, 867
Portal canals, 873
fissure of liver, 864
vein, 479, 867, 873
blood of, xliii
circulation in, clxvi
Portio dura, 610
mollis of seventh cranial nerve, cxlix, 615
Porus opticus (optic pore), 726
Postsphenoid bone, 68
Pouch, recto-vesical, 857
Pouches, laryngeal, 913
Poupart's ligament, 249
Preformative membrane, 797
Pregnancy, changes in uterus during, 987
Premaxillary bone, 70
Premolar teeth, 782
Prepuce (*præputium*, the foreskin), 955
development of, 1001
Presphenoid bone, 68
Pressure, effects of on skull, 74
Prevertebral fascia, 198
plexus, 687
Primary cerebral vesicles, 575
Primitive band or axis of nerve-fibre, cxxxvi
groove, 573
kidneys, 993
sheath of nerve-fibre, cxxxvi
trace in embryo, 15
vertebræ, 16
Primordial (*primus*, first; *ordior*, I begin) cranium, 65
kidneys, 993
utricle, x, xiii
in cartilage, lxxxi
vertebræ, 16
Process of bone, lxxxviii
acromion, 76
angular of frontal bone, 34
auditory, external, 37
basilar, 29, 31, 59
clinoid, posterior, 39
cochleariform, 38
coracoid, 76
coronoid of lower jaw, 52
ulna, 82
cuneiform, 43
ensiform, 23
falciform, 293
frontal, lateral, 65
middle, 65
hamular, 41
of helix, 742

Process—*continued.*
malar, 45
mastoid, 36, 59
nasal, 46
external, 65
internal, 65
odontoid, 9
olivary, 39
orbital of palate bone, 47
pterygoid, 41, 59
pyramidal, 47
sphenoidal, 48
spinous of sphenoid bone, 40, 59
styloid of temporal bone, 37, 59
of radius, 81
of ulna, 83
supracondyloid, 80
turbinated, superior and inferior, 43
uncinate, 43
vaginal, 37
vermiform, 522
xiphoid, 23
zygomatic, 36
Processes, ciliary, 717
of incus, 749
of malleus, 748
mammillary, of lumbar vertebræ, 7
of vertebræ, articulating, 4, 6, 7, 8, 9, 10
spinous, 4, 6, 8, 10
transverse, 4, 6, 8, 10
serial relations of, 116
Processus a cerebello ad cerebrum, 552, 554
a cerebello ad testes, 522
arciformes, 517
brevis, 748
cochleariformis (spoon-shaped process), 38
cuneatus (wedge-shaped process), 518
gracilis, 748
obtusus of the malleus, 748
reticularis of spinal cord, 511
vaginalis peritonæi, 965, 1000
Prognathous (προ, forward; γναθος, a jaw) skulls, 73
Promontory of sacrum, 10
of tympanum, 746
Pronation and pronator (*pronus*, having the face downward), 228
Prosencephalon (προς, before; ἐγκεφαλον, the brain), 577
PROSTATE (προ, before; ἱστημι, I place) GLAND, 952
anterior, 963
development of, 1001
fluid of, 954
levator muscle of, 953
structure of, 954
surgical anatomy of, 1040
vessels and nerves of, 954
Prostatic fluid, 954
plexus, 703
Postatic—*continued.*
portion of urethra, 961
sinus, 961
Protoplasm (πρωτος, first; πλασσω, I form), xv
movements of, xix
Protoplast, xv, xxiv
Protuberance, occipital, external, 30
internal, 31
Proximate constituents of the body, 5
Psoas (ψοα, the loin) muscles, 272, 273
Pterygoid (πτερυξ, a wing; εἶδος, shape) arteries, 356
bones, 68
canal, 42
foramen or canal, 42
fossa, 41
muscles, 181
processes, 41, 59
Pterygo-maxillary fissure, 57
ligament, 176
Pterygo-palatine artery, 357
canal, 41
Pubic arch, 97
artery, 424, 434
articulation, 149
bone, 95
ossification of, 110, 111
Pubo-prostatic ligaments, 952
Pudic artery. *See* ARTERY
nerve, 670
Pulmonary artery. *See* ARTERY
circulation, clxvi
plexuses, 623, 903
Punctum lachrymale, 709
Puncture of bladder, 1042
Pupil of eye, 718
form and size of, 719
membrane of, 721
Pyloric artery, 408
orifice of stomach, 831
Pylorus (πυλωρος, a gate-keeper), 838
Pyramid in cerebellum, 524
in thyroid body, 921
in tympanum, 746
Pyramidal bone, 84
process of palate bone, 47
Pyramidalis muscle, 255
Pyramids of medulla oblongata, anterior, 515
development of, 577
posterior, 516
of kidney, 929
Pyriformis (*pyrus*, a pear; *forma*, shape) muscle, 268

RACEMOSE (*racemus*, a cluster of grapes) glands, ccxxii
Radial artery, 394
nerve, 653
Radio-carpal articulation, 142
Radio-ulnar articulation, 138
Radius (a ray, or the spoke of a wheel), 80

Radius—*continued*
connection of, with ulna, 138
ossification of, 90
Ramus (a branch) of ischium, 96
of lower jaw, 51
of pubic bone, 95
Ranine (*rana*, a frog; also a swelling under the tongue) artery, 349
Raphe (ῥαφη, a seam; from ῥαπτω, I sew) of corpus callosum, 542
of medulla oblongata, 517, 519
perinæum, 1038
pons Varolii, 521
scrotum, 964, 1001, 1038
tongue, 805
Rathke's reseaches on the fœtal heart, 527
Receptaculum chyli, 487, 1075
Recto-uterine folds, 986
Recto-vesical fascia, 260
folds, 947
pouch, 857
Rectum (*intestinum rectum*, the straight intestine), 856
dissection of, 1077
position and course of, 856
structure of, 858
surgical anatomy of, 1041
vessels and nerves of, 858
Rectus muscle. *See* MUSCLES
Recurrent arteries. *See* ARTERY
nerves. *See* NERVES
Reflex movements, cxxxii
Regeneration of areolar tissue, lxxiv
of bone, cxv
cartilage, lxxxv
fibrous tissue, lxxvi
hair, ccxiv
mucous membranes, cci
muscular tissue, cxxviii
nails, ccviii
nerves, clxv
pigment, lxv
serous membranes, cxciii
skin, ccxviii
textures, xxvi
Region, abdominal, dissection of, 1069
cervical, dissection of, 1052
gluteal, dissection of, 1078
hypogastric, 824
ischio-rectal, 1037
sublingual, dissection of, 1057
submaxillary, dissection of, 1057
Reil, island of, 532, 534
Reissner, membrane of, 760, 761
Renal (*ren*, the kidney) artery, 414, 935
plexus, 701
Renes succenturiati, 939
Renovation, molecular, xxv
Reproduction, i
Respiration, organs of, 888
movements of, 246
Restiform (*restis*, a cord; *forma*, shape) bodies, 516, 518, 519
development of, 577
Rete mirabile, lv, clxviii
Rete mucosum, ccii
Rete vasculosum testis, 970
Reticular tissue, lxx, lxxix
Reticulum (dim. of *rete*, a net) of nervous tissue, cxli, 511
Retiform (*rete*, a net; *forma*, shape), connective tissue, lxxix
of brain and spinal cord, cxli
Retina (*rete*, a net), 725
ciliary part of, 730
columnar layer of, 727
connection of elements of, 728
contents of in yellow spot, 729
development of, 738
granular layer of, 727
internuclear layer of, 728
limiting membrane of, 728
nervous layer of, 728
physical characters of, 725
structure of, 726
vessels of, 729
Retinacula (restraining bands) of ileo-cæcal valve, 853
of tendons. *See* Annular Ligaments
Retrahens auriculam muscle, 171
Retroperitoneal membrane, 826
Retzius' classification of skulls, 73
Rhomboideus (ῥομβος, a rhomb, or equilateral four-sided figure with oblique angles; εἶδος, shape) muscles, major and minor, 202
Ribs, 24
articulations of, 128
cartilages of, lxxxiii
development of, 27
Rigor mortis, cxxxi
Rima (cleft) of pudendum, 977
glottidis, 910, 912
Ring, abdominal, external, 250, 1019
internal, 258, 1023
crural, 258, 1033
Risorius (*rideo*, I laugh) muscle, 176
Rivini, ducts of, 818
Rods of Corti in ear, 764
of retina, 727
Rolando, fissure of, in the brain, 533
Root-sheath of hair, ccx
Rosenmüller, organ of, 992
Rostrum (a beak) of corpus callosum, 542
of sphenoid bone, 39
Rotation, 120
Rotatores spinæ, 238
Rotula (dim. of *rota*, a wheel), 103
Rugæ (wrinkles) of mucous membrane, cxcvi
of stomach, 835
vagina, 981
Ruysch, tunic or membrane of, 717

SAC of hernia, 1025, 1035
lachrymal, 709
of omentum, 827

Saccular (*sacculus*, a little bag) glands, ccxxii
Saccule of larynx, 912
of vestibule, 757
Sacculus, vesical, 951
Sacral (*sacrum*) arteries, 418, 430
foramina, 11
nerves, 668
plexus, 669
Sacro-iliac articulation, 147
Sacro-lumbalis muscle, 234
Sacro-sciatic foramina, 149
ligaments, 148
Sacro-vertebral ligament, 147
Sacrum (*os sacrum*, the sacred bone; because formerly offered in sacrifices), 10
articulations of, 147
ossification of, 19, 21
Sacs of milk-teeth, 794, 795
of permanent teeth, 801
Sagittal (*sagitta*, an arrow) suture, 55
Saliva, 818
Salivary glands, 814
development of, 819
Salivine, 818
Salpingo-pharyngeus (σαλπιγξ, a trumpet; φαρυγξ, the pharynx) muscle, 189
Santorini, cartilages of, 908
fissures of, 742
Saphenous (σαφηνης, manifest) nerve, external, 666
opening, 292
veins, 475, 476
Sarcode (σαρξ, flesh), contractions in, xx
Sarcolemma (σαρξ, flesh; λεμμα, a husk), cxviii
Sarcous elements of muscle, cxix
Sarkin, xl, cxxviii, cxxxiv
Sartorius (*sartor*, a tailor) muscle, 273
Satellite (*satelles*, an attendant) veins, cxxiii
Scala tympani (*scala*, a stair), 756
vestibuli, 756
Scalenus (σκαληνος, with unequal sides) muscles, 193, 195
Scaphoid (σκαφη, a skiff or boat; εἶδος, shape) bone of foot, 108
ligaments of, 161, 163
ossification of, 115
bone of hand, 84
ligaments of, 142
ossification of, 93
Scapula (probably = σκαπανη, a spade), 74
ligaments of, 134, 136
ossification of, 89, 90
Scapular artery, 367, 373
Scapulo-clavicular articulation, 134
Scarf-skin, liv, cci
Scarpa's foramina, 45
triangle, 434
Schindylesis (σχινδυλεω, I split), 119
Schleiden's views on cell-growth, xix
Schlemm, canal of, 721
Schneiderian membrane, 774
Schwann's views on cell-growth, xix
Sciatic (ἰσχιον, the hip) artery, 429
nerves, 673, 675
Sclerotic (σκληρος, hard) coat, 711
structure of, 713
Sclerotome (σκληρος, hard; τεμνω, I cut), 1
Scrobiculus (a small pit) cordis, 824
Scrotal hernia, 1025
Scrotum (a hide), 964
dartos tunic of, 257
development of, 1001
Sebaceous (*sebum*, suet) glands, ccxvii
development of, ccxviii
Secondary deposits in cells, xii
SECRETING APPARATUS, ccxix
cells, ccxx
fringes, ccxxi
glands, ccxviii
membrane, ccxxi
SECRETION (*secerno*, I separate), ccxix
cell-agency in, ccxx
Segmentation of yelk-mass in ovum, xv
Segments of trunk, 1
relation of limbs to, 117
Sella Turcica (Turkish saddle), 39
Semen, 975
Semicircular canals, 754
membranous, 758
Semilunar bone, 84
Semimembranosus muscle, 271
Seminal granules, 956
ducts, 974
vesicles, 973
Seminiferous tubes, 969
Semipenniform muscles, cxvii
Semispinalis muscle, 237
Semitendinosus muscle, 271
Sensation, cxxxii
Sense, muscular, cxxviii, cxxix
Senses, organs of, 705
Sensibility of muscles, cxxix
Sensory terminal organs, cl
Septa, intermuscular, of arm, 230
foot, 296
thigh, 293
Septula renum, 929
Septum (a partition, from *sepio*, I hedge in) of auditory ampullæ, 758
crurale, 1035
of heart, auricular, 309
development of, 323
fibres of, 320
ventricular, 310
lucidum, 543, 545
of medulla oblongata, 517, 519
nasi, 771, 772
of nose, osseous, 61
pectiniforme (comb-like partition), 957
of pons Varolii, 521
scroti, 964
sphenoidal, 39

Septum—*continued.*
subarachnoid, 565
of tongue, 811
Serial homology, 2
relation of parts of vertebræ, 21
Serolin, xl
Serosity, xxxix
SEROUS MEMBRANES, General Anatomy of, cxci
arrangement of, cxci
epithelium of, liii
fluid of, cxciii
folds of, cxci
inflammation of, cxciii
reparation of, cxciii
structure and properties of, cxcii
vessels and nerves of, cxcii
Serous vessels, clxxx
Serrated (*serra*, a saw) suture, 119
Serratus muscle. *See* MUSCLES
Serum of blood, xxvii, xxxix
of chyle, xlix
lymph, xlviii
muscle, cxxviii
Sesamoid (σησαμον, a kind of small grain; εἶδος, shape) bones of fingers, 88
of toes, 110
fibro-cartilages, lxxxvii
Sheath of arteries, clxviii
crural, 293
of muscles, cxvi
of nerve-fibre, medullary, cxxxvi
primitive, cxxxvi
of nerves, common, cxliv
of funiculi, cxliv
Sheaths, synovial, cxcv
Shin-bone, 103
Short bones, lxxxviii
Shoulder-joint, bones of, 74
compared with pelvis, 116
dissection of, 1064
ligaments of, 136
Sigmoid (C, a form of the letter σιγμα, *sigma*; εἶδος, shape) artery, 412
cavity of ulna, 82
notch, lower jaw, 52
flexure of colon, 854
valves, 307
aortic, 313
pulmonary, 310
Sinus (a hollow) of aorta, 335
basilar, 464
cavernous, 463
nerves in, 594
circular, 463
circularis iridis, 721
coronary, of heart, 310, 483
falciformis inferior, 462
falciformis superior, 462
frontal, 34, 64
of jugular vein, 459
kidney, 928
lateral, 462
longitudinal, inferior, 462
Sinus—*continued.*
longitudinal, superior, 462
lymph, clxxxvii
maxillary, 46, 64
occipital, anterior, 464
posterior, 463
pedis, 161
petrosal, inferior, 463
superior, 463
of portal vein, 480
pocularis (cup-like sinus), 961
prostatic, 961
quartus or straight sinus, 462
transverse, 462, 464
uro-genitalis, 995, 1001
of vestibule, 757
Sinuses, cranial, 64, 461
ethmoidal, 64
frontal, 64
of larynx, 913
maxillary, 46, 64
sphenoidal, 39, 64
of Valsalva, 308
aortic, 313, 335
pulmonary, 311
venous, of cranium, 461
confluence of, 462
dissection of, 1051
of veins, clxxiv
SKELETON (σκελλω, I dry), 2
adapted to erect posture, 117
SKIN, General Anatomy of, cci
basement membrane of, cciii
chemical composition of, ccvi
cuticle. *See* Cuticle
cutis vera, derma, or corium, cciii
development of, ccvi
epidermis, cci
functions of, ccxviii
furrows of, cciv
glands of, sebaceous, ccxvii
sudoriferous, ccxvi
lymphatics of, ccv
Malpighian layer of, ccii
nerves of, ccvi
papillæ of, cciv
pigment of, ccii
reproduction of, ccxviii
rete mucosum of, ccii
structure of, cciii
thickness of, cciv
true, cciii
vessels of, ccv
vital properties of, ccxviii
SKULL, anterior region of, 55
base of, external, 59
internal, 61
bones of, 29
analogy with vertebræ, 94
development of, 64
external surface, 55
forms of, 72
fossæ of, 61
general conformation of, 55
internal surface, 60

SKULL—*continued.*
internal fossæ of, 61
lateral region of, 57
muscles of, 169
superior region of, 55
sutures of, 53
vertebral theory of, 71
Smegma præputii, 955
Sœmmering's classification of cranial nerves, 582
Solar (*sol*, the sun) plexus, 699
Soleus (*solea*, a sandal, or sole of a shoe, also a sole fish), 284
Somatome (σωμα, a body; τεμνω, I cut), 1
Space, perforated, anterior, 539
posterior, 536
Spaces, Haversian, of bone, xciii
SPERMATIC cord, coverings of, 965, 1023
vessels and nerves of, 967
relation to inguinal hernia, 1025, 1027, 1029
structure of, 1023
fascia, 965
filaments, 976
Spermatic artery, 414, 975
Spermatozoa (σπερμα, seed; ζωον, an animal), 975, 976
Sphenoid (σφην, a wedge; ειδος, shape) bone, 38
ossification of, 68
Sphenoidal fissure, 41, 57, 61
process of palate bone, 48
septum, 39
sinus, 39, 64
spongy bones, 39, 40, 69
Spheno-maxillary fissure, 57
fossa, 57
Spheno-palatine artery, 357
foramen, 48, 58, 63
ganglion, 603, 1057
Spheno-parietal suture, 55
Spheroidal epithelium, liii, lviii
Sphincter (σφιγγω, I bind) of rectum, external, 262
internal, 859
oris, 175
of pupil, 719
vaginæ, 266, 932
vesicæ, 949
Spigelius lobule of, 864
SPINAL CORD, Descriptive Anatomy of, 502
blood-vessels of, 567
cells of grey matter in, 510
central canal of, 508
ligament of, 503
columns of, 506
course of fibres in, 511
commissures of, 507
connective tissue of, 510
development of, 574
dissection of, 1061
fissures of, 506
grey matter of, 509
SPINAL CORD—*continued.*
length and form of, 504
ligaments of, 503, 566
membranes of, 502, 563, 564
minute structure of, 509
origin of nerves from, 511
sections of, 511
vesicular tract of, 510
weight of, 572
Spinal arteries. *See* ARTERIES
SPINAL NERVES, 628. *See* NERVES
divisions of, anterior, 635
posterior, 632
roots of, 630
Spinales. *See* MUSCLES
Spine. *See* Vertebral Column
Spine, ethmoidal, 39
hæmal, 23
of ilium, anterior and posterior, 94
ischium, 96
nasal, 34, 45
neural, 22
occipital, 30
of os pubis, 95
scapula, 75
tibia, 103
Splanchnic nerves, 695, 696
Splanchnology (σπλαγχνα, bowel; λογος, discourse), 779
Spleen (σπλην), 883
accessory, 884
coats of, 884
corpuscles of, 887
development of, 888
dissection of, 1074
hilus or fissure of, 883
lymphatics of, 887
nerves of, 887
position of, 824, 883
pulp of, 886
size and weight of, 884
structure of, 884
trabeculæ of, 884
vessels of, 408, 886
Splenculi (little spleens), 884
Splenic arteries, 418, 886
flexure of colon, 854
Splenius (*splenium*, a pad) muscle, 234
Spongy bones, ethmoidal, 43
inferior, 50, 70
sphenoidal, 39, 40, 69
cartilages, lxxxvi
structure of bone, xc
Spot, germinal, of ovum, xv, 990
Squamous (*squama*, a scale) suture, 119
Stapedius (*stapes*) muscle, 751
Stapes (a stirrup), 749
development of, 66
Stearin (στεαρ, tallow), lxvii
Stellulæ of Verheyen, 937
Stenson, duct of, 816
foramina of, 45
Sternal artery, 374

Sterno-clavicular articulation, 134
Sterno-hyoid muscle, 191
Sterno-mastoid artery, 351
muscle, 193
Sterno-thyroid muscle, 191
Stimuli of muscular contraction, cxv, cxxx
Stomach, 830
alveoli of, 835
changes in colour of, after death, 834
coats of, 832
connections of, 831
development of, 860
dimensions of, 831
dissection of, 1073
epithelium of, 837
follicles of, 837
glands of, 836
lymphatics of, 838
mucous membrane of, 834
muscular coat of, 832
nerves of, 838
position of, 826, 830
pylorus, 838
rugæ of, 835
shape of, 831
structure of, 832
tubules of, 835
vessels of, 407, 837
Stratified epithelium, liv
Stratum bacillorum (layer of rods), 727
ferrugineum (rust-coloured layer), cxlviii
Stria cornea (the horny streak), 550
vascularis, 768
Striæ longitudinales, 542
Striated layers of arteries, clxix
Stripes, cross, of muscle, cxvii
cause of, cxix
Stroma (στρωμα, a bed), hilus-, of lymphatic glands, clxxxvii
intertubular, of kidney, 938
of ovaries, 989
of suprarenal bodies, 939, 941
Structural elements of the body, iv
Stylo-glossus muscle, 186
Stylo-hyoid ligament, 133
muscle, 184
Styloid (στυλος, a style or pen; εἶδος, shape) process, 37, 59
Stylo-mastoid artery, 353, 752, 768
Stylo-maxillary ligament, 133, 197
Stylo-pharyngeus muscle, 187
Subarachnoid fluid, 566
space, 565
Subclavian artery. *See* ARTERY
Subcrureus muscle, 276
Sublingual artery, 348, 349, 818
gland, 817
Sublobular veins of liver, 870
Submaxillary ganglion, 609
gland, 816
muscles, 183
Submental artery, 350, 351, 818
Submucous coat of intestines, 841
Suboccipital nerve, 632
Subperitoneal layer of areolar tissue, 826
Subscapular arteries, 373, 379
fossa, 74
nerve, 645
Substantia cinerea gelatinosa, 507, 519
spongiosa, 508
Sudoriferous glands, ccxvi
development of, ccxvii
Sulci (furrows) in brain, 531
Sulcus frontalis, 35
spiralis, 761
Superciliary ridge, 33
Supination (*supinus*, lying on the back), muscles of, 228
Supinator muscles, 220, 223
Supra-acromial artery, 373
Supracondyloid eminence, 79
Supramaxillary nerve, 615
Supraorbital artery, 360
foramen, 34, 56, 57
nerve, 598
SUPRARENAL BODIES, 939
accessory, 942
cortical part of, 939
development of, 994
function of, 942
medullary part of, 940
nerves of, 941
size and weight of, 939
stroma of, 939, 941
vessels of, 941
Suprarenal artery, 413
plexus, 699
Suprascapular artery, 366, 371
nerve, 644
Supraspinatus muscle, 209
Supraspinous fossa, 74
Supratrochlear nerve, 597
Sural (*sura*, the calf) artery, 442
SURGICAL ANATOMY, 1005
of arteries, brachial, 1010
carotid, common, 1005
epigastric, 1023
iliac, common, 1012
external, 1014
internal, 1014
femoral, 1015
subclavian, 1007
ischio-rectal fossæ, 1043
hernia, femoral, 1031
inguinal, 1018, 1025
perinæum, 1037
peritonæum, at groin, 1022
Sustentacular (*sustentaculum*, a support) connective tissue, lxxix
Sustentaculum tali (the support of the astragalus), 107
Suture (*sutura*, a seam), forms of, 119
coronal, 54
frontal, 55, 67
fronto-parietal, 54
lambdoidal, 54
occipito-mastoid, 55
occipito-parietal, 54
parietal, 55

Suture—*continued*.
parieto-mastoid, 55
sagittal, 55
spheno-parietal, 55
squamous, 55
temporo-parietal, 55
Sweat-glands, ccxvi
Sylvius, aqueduct of, 525, 550
fissure of, 530. *See* Fissure
ventricle of, 545
Sympathetic nerve. *See* NERVE, SYMPATHETIC
Symphysis (συν, with, together; φυω, I grow) of lower jaw, 51
pubic, 95, 100, 149
sacro-iliac, 147
Synarthrosis (συν, with, together; ἄρθρον, a joint), 119
Synchondrosis (συν, with, together; χονδρος, cartilage), sacro-iliac, 147
Synostosis (συν, with, together; ὀστεον, a bone), 73
Synovia (συν, with; ὠον, an egg), cxcv
Synovial bursæ, cxciv
capsules, cxciii
fluid, cxcv
folds or fringes, cxciv
membranes, cxciii
of ankle, 160
articular, cxciii
of atlas, 125
of axis, 126
bursal, cxciv
carpal, 144
costo-sternal, 130
costo-vertebral, 129
of elbow-joint, 141
of hip, 152
intervertebral, 122
of knee-joint, 156
of lower jaw, 133
metacarpal, 146
metatarsal, 166
peroneo-tibial, 158, 159
radio-carpal, 142
radio-ulnar, 139
of ribs, 129
sacro-vertebral, 147, 35
scapulo-clavicular, 1
of shoulder-joint, 137
sterno-clavicular, 134
tarsal, 162, 163, 164
tarso-metatarsal, 165
vaginal, cxcv
of vertebræ, articulating, 123
vesicular, cxciv
vessels of, cxciv
sheaths, cxcv
Syntonin (συν, together; τεινω, I stretch), ccxxviii
Systemic circulation, clxvi
vessels, 332
Systems, organic, iii

TABLES of skull, 60
Tabular bones, lxxxviii
epithelium, liii
Tactile (*tactus*, touch) corpuscles, cli, ccvi
papillæ, ccvi
Tænia (ταινια, a band or ribbon) semicircularis, 543, 550
Tænia hippocampi, 544, 546
Talo-calcaneal (*talus*, the astragalus; *calcaneum*, heel-bone) ligaments, 160
Talo-scaphoid (*talus*, the astragalus; *scaphoid*) ligament, 161
Talus (a die), 107. *See* Astragalus
Tapetum (a carpet), 718
Tarsal (*tarsus*, the cartilage supporting the eye) cartilages, 706
Tarso-metatarsal articulations, 164
Tarsus (ταρσος, the upper surface of the foot), 106
compared with carpus, 115
ligaments of, 164
ossification of, 111, 115
Tauro-cholic (*taurin* [ταυρος, a bull]; χολη, bile) acid, 879
Taxis (ταξις, an arranging) in femoral hernia, 1036
inguinal hernia, 1030
TEETH, 780
arrangement in jaws, 783
bicuspid, 782
canine, 781
cavity of, 785
cement of, 791
formation of, 799
changes in jaw during growth of, 804
characters of, general, 780
classification of, 780
crusta petrosa of, 791
cuspidate, 781
dentine of, 785
formation of, 797
tubules of, 786
dentine, secondary of, 792
development of, 792
enamel of, 789
formation of, 798
eye, 782
follicular stage of, 793
incisor, 781
intertubular substance of, 787
ivory of, 785
formation of, 798
milk, 784
molar, 783
nerves of, clv, 805
osteodentine of, 792
permanent, 780
calcification of, 803
cavities of reserve of, 801
development of, 800
eruption of, 803
special characters of, 781
primitive groove of, 793

TEETH—*continued.*
pulp, dental, of, 785
primitive, 796
sacs of, 794
structure of, 784
temporary, 784
development of, 792
eruption of, 799
follicular stage of, 793
papillary stage of, 793
saccular stage of, 794
shedding of, 802
vessels of, 805
wisdom, 783
Tegmentum of crura cerebri, 556
Tela choroidea (the choroid web), 548
Temporal (*tempora*, the temples) arteries, 353, 354, 356
bone, 35
fascia, 197
fossa, 57
muscle, 181
nerve. *See* NERVE
Temporo-maxillary articulation, 132
Temporo-parietal suture, 55
Temporo-sphenoidal suture, 55
Tendo Achillis (tendon of Achilles), 285
palpebrarum, 171
Tendon, cordiform or central, of diaphragm, 245
conjoined, 250, 1022
Tendons (τείνω, I stretch), lxxiv
connection with muscles, cxxi
Tensor (*tendo*, I stretch). *See* MUSCLES
Tentorium (a tent, from *tendo*, I stretch), 563
Tesselated (*tessella*, dim. of *tessera*, a small quadrangular stone in a pavement) epithelium, liii
TESTES (testicles), 963, 967
capsule of, 968
coni vasculosi of, 970
coverings of, 963
vessels and nerves of, 967
descent of, 1000
development of, 995
epididymis of, 967
excretory duct of, 971
glandular substance of, 969
gubernaculum of, 1000
lobes of, 969
mediastinum of, 969
rete vasculosum of, 970
secretion of, 975
septum of, 968
structure of, 969
tubuli of, 969
recti of, 970
tunica albuginea of, 968
vaginalis of, 966
vasculosa of, 969
vas deferens of, 971
vasa efferentia of, 970
recta of, 970
vessels and nerves of, 975
TESTES—*continued.*
(in cerebrum), 554
muliebres, 988
TEXTURES in general, iii
chemical composition of, v
development of, ix
enumeration of, iii
nutrition and regeneration of, xxiv
particular. *See* TISSUE, &c.
permeability of, iv
physical properties of, iv
vital properties of, vii
Thalami optici (optic couches), 550, 558,
development of, 579
grey matter of, 561
Thebesius, foramina of, 309
valve of, 310
Theca vertebralis (vertebral sheath), 502, 563
Thenar (θέναρ, the palm of the hand) prominence, 225
Thigh, bone of, 100
dissection of, 1080
muscles of, 266
Thoracic (*thorax*) arteries. *See* ARTERY
duct, 487
Thorax (θώραξ, a breast-plate), 27
bones of, 23
dissection of, 1066
muscles of, 240
Thumb, muscles of, 225
action of, 229
Thymic (*thymus* gland) artery, 374
THYMUS GLAND, 923
central stem of, 924
chemical composition of, 924
development of, 925
fluid of, 924
lobes of, 923
lymphatics of, 925
structure of, 924
vessels and nerves of, 925
Thyro-arytenoid ligament, 910
muscle, 916
Thyro-hyoid ligaments, 909
muscle, 192
Thyroid artery, 346
axis, 371
THYROID (θυρεός, a shield; εἶδος, shape) BODY OR GLAND, 920
development of, 922
fluid of, 922
isthmus of, 920, 921
levator muscle of, 921
lobes of, 920
structure of, 921
vessels and nerves of, 922
weight of, 921
Thyroid cartilage, 906
Thyro-pharyngeus muscle, 188
Tibia (a pipe or flute, from its supposed resemblance), 103
compared with ulna and radius, 115
ligaments of, 158
ossification of, 111, 112

Tibial artery. *See* ARTERY
nerve. *See* NERVE
TISSUE, adipose, lxv
areolar, cellular, or filamentous, lxix
cartilaginous, lxxx
cavernous, clxxx
connective, lxix
special varieties of, lxxviii
homogeneous, lxxix
jelly-like or mucous, lxxviii
retiform, lxxix
cuticular, lii
cytogenous, lxxix
elastic, lxxvi
epidermic, lii
epithelial, lii
erectile, clxxx
fibrous, lxxiv
filamentous, lxix
muscular, cxv
nervous, cxxxi
osseous, lxxxvii
reticular, lxxix
Toe, great, muscles of, 288, 289
Toes, bones of, 110
movements of, 166
muscles of, 280, 286, 289
Tomentum (flock of wool, hair, &c.), 564
TONGUE, 805
dissection of, 1058
frænum of, 805
glands of, 809
mucous membrane of, 805
muscles of, 185, 809
nerves of, 808, 812
papillæ of, circumvallate, 806
conical and filiform, 807
fungiform, 807
secondary, 808
raphe of, 805
septum of, 811
vessels of, 812
Tonicity (τονος, tension) of arteries, clxxi
Tonsillar artery, 350, 814
Tonsils, 813
vessels and nerves of, 814
Topographic anatomy, 1
Torcular (a wine- or oil-press) Herophili, 462
Touch-bodies, cli
Trabeculæ (dim. from *trabs*, a beam) of corpus cavernosum, 957
lateral, of primitive cranium, 65
of lymphatic glands, clxxxvii
of spleen, 884
Trabs cerebri (corpus callosum), 541
TRACHEA (*arteria trachea*, the rough artery; τραχυς, *rough*), 888
cartilage and fibrous membrane of, 890
development of, 904
elastic fibres of, 891
glands of, 892
mucous membrane of, 892
muscular fibres of, 891
TRACHEA—*continued.*
situation of, 888
structure of, 890
vessels and nerves of, 892
Trachelo-mastoid (τραχηλος, the neck; *mastoid*) muscle, 235
Tract, optic, 536, 554
Tractus intermedio-lateralis, 510
foraminosus spiralis, 756
Tragus (τραγος, a goat), 741
muscles of, 743
Transitional epithelium, lviii
Trapezium (τραπεζιον, dim. of τραπεζα, a table), 85
Trapezoid bone, 85
ligament, 135
Trapezius muscle, 200
Trefoil tendon of diaphragm, 245
Triangle, cervical, anterior, 1053
posterior, 1052
of Hesselbach, 1027, 1029
Scarpa's, 434
Triangular ligament of urethra, 260
Tricuspid (*tres*, three; *cuspis*, the point of a weapon) valve, 310
Trigone (triangle, from τρεις, three; γωνια, an angle) of bladder, 948
Trigonum vesicæ, 948
Triquetral (*triquetrus*, three-cornered) bones, 55
Trochanter (τροχαντηρ, τροχαινω, τροχος, words implying turning) major, 100
minor, 101
Trochlea (τροχιλεα, a pulley) of humerus, 79
Trunk, articulations of, 121
muscles of, 233
attaching upper limb to, anterior, 203
posterior, 200
nerves of, 682, 684
relation of limbs to segments of, 117
Tube, Eustachian, 747
membranous, of nerve-fibre, cxxxvi
Tuber annulare, 521
calcis, 107
cinereum, 538
Tubercle, grey, of Rolando, 519
laminated, 525
of Lower, 310
Tubercula quadrigemina, 552
development of, 578
grey matter of, 561
Tuberculum pharyngeum, 819
Tuberosity, bicipital, 80
of ischium, 96
palate bone, 47
superior maxillary bone, 45
Tubes, Fallopian, 991
development of, 996
uriniferous, 930
convoluted, 930
development of, 994
looped, 930, 934

Tubes—*continued.*
origin and course of, 933
straight, 930
Tubular glands, cexxii
nerve-fibres, cxxxv
Tubules, dental, 786
Tubuli contorti (twisted or convoluted tubes) of kidney, 930
recti of kidney, 970
seminiferi, 969
uriniferi, 929
origin and course of, 933
Tulpius, valve of, 852
Tunica adiposa of kidney, 926
albuginea of testicle, 968
of ovary, 988
choroidea, 716
chorio-capillaris, 717
erythroides (ἐρυθρος, red; εἶδος, form), 965
Ruyschiana, 717
vaginalis, 966
hernia in, 1025
vasculosa testis, 969
eye, 716
Turbinated (coiled, from *turbo*, a whirl) bones. *See* Spongy bones
Tutamina oculi (defences of the eye), 705
Tympanic (*tympanum*, the drum of the ear) artery, 356, 752
plate, 37
TYMPANUM (τυμπανον, a drum), or middle ear, 744
apertures of, 746
bones or ossicula of, 748
cavity of, 744
development of, 769
ligaments of, 749
membrane of, 745
lining, 751
secondary, 746
muscles of, 749
scala of, 756
vessels and nerves of, 752
walls of, 745
Tyson's glands, 955

ULNA (ὠλενη, the elbow), 81
compared with bones of leg, 115
ossification of, 90
ligaments of, 138
Umbilical (*umbilicus*, the navel) cord, tissue of, lxxii
fissure of liver, 864
region, 824
contents of, 826
Umbilicus, cicatrix of, 255
Unciform (*uncus*, a hook; *forma*, shape) bone, 86
Uncinate (*uncus*, a hook) process of ethmoid bone, 43
Unguis os (the bone like a nail), 50
Upper limb, articulations of, 134
bones of, 74

Upper Limb—*continued.*
compared with lower, 115
dissection of, 1059
fasciæ of, 229
muscles of, 198
nerves of, cutaneous, 683
of muscles, 685
Urachus (οὐρον, urine; ἐχω, I hold), 945
formation of, 995
Urea in blood, xl
URETERS (οὐρεω, I pass urine), 942
course of, 942
development of, 994
orifices of, 948
structure of, 943
varieties of, 943
vessels and nerves of, 943
URETHRA (οὐρον, urine), female, development of, 980
mucous membrane of, 980
muscles of, 266
orifice of, 978
male, 959
bulb of, 958
crest of, 961
development of, 1001
fossa navicularis of, 962
glands and lacunæ of, 962
length of, 959
ligament of, triangular, 260, 1040
mucous membrane of, 962
muscles of, 265, 962
orifice of, external, 955
internal, 948
portion of, membranous, 962
bulbous, 962
prostatic, 961
spongy, 962
sinus pocularis of, 961
Uric acid, xl, cxxviii, cxxxiv
Urinary bladder, 944. *See* BLADDER
organs, 926
development of, 992
Urine, 938
Uriniferous tubes, 929
development of, 994
Uterine artery, 422, 987
UTERUS (womb), 982
arbor vitæ of, 984
body of, 983
cavity of, 984
cervix, or neck, 983
changes in, 987
development of, 996
double, 998
epithelium of, 985
fibres of, 985
functions of, 982
fundus of, 983
glands of, 985
gravid, changes in, 987
nerves of, 704
ligaments of, anterior and posterior, 985

UTERUS—*continued.*
ligaments of,
broad, 986
round, 986
mucous membrane of, 985
muscular tissue, growth of during gestation, cxxvii
nerves of, 704, 987
os, or mouth of, external, 983
internal, 984
tincæ of, 982
position of, 825, 982
structure of, 984
tissue, proper, of, 984
vessels of, 422, 987
Utricle (*utriculus*, a small bag), x, xiii
of male urethra, 961
of vestibule of the ear, 757
Uvea (*uva*, a cluster of grapes), 719
Uvula (dim. of *uva*) of bladder, 948
of cerebellum, 524
of throat, 189
muscle of, 190

VAGINA (sheath), 980
columns of, 981
development of, 1001
sphincter of, 266, 982
structure and connections, 982
Vaginal artery, 422
process, 37
synovial membranes, cxcv
Valsalva, sinuses of, 308, 311, 313
Vallecula of cerebellum, 523
Valve of Bauhin, 852
Eustachian, 309, 325
of foramen ovale, 325
ilio-cæcal, or ileo-colic, 852
mitral, or bicuspid, 313
of Thebesius, 310
tricuspid, 310
of Tulpius, 852
of Vieussens, 554
Valves, auriculo-ventricular, 305
of Kerkring, 842
lacrymal sac and canals, 710
lymphatics, clxxxv
sigmoid, or semilunar, of aorta, 307
pulmonary, 310
of veins, clxxiv
Valvulæ conniventes, cxcvi, 842
Varicose nerve-fibres, cxxxvii
Vas aberrans of testis, 972
deferens, 971, 1023
development of, 996, 999
spirale (spiral vessels), 767
Vasa aberrantia, brachial, 385
afferentia and efferentia of lymphatic glands, clxxxvi
brevia of the stomach arteries, 409
veins, 481
chylifera, 491
efferentia of testis, 970
development of, 999
lactea, 491, 844

Vasa—*continued.*
recta of kidney, 936
of testes, 970
serosa, clxxx
vasorum, arteries, clxxi
veins, clxxiv
lymphatics, clxxxv
vorticosa, 717, 722
Vascula serpentina, 19, 69
Vascular glands, ccxxvi
Vaso-motorial nerves, clxiii
Vegetable structures, formation of, x
VEINS, General Anatomy of, clxxii
anastomoses of, clxxiii
coats of, clxxiii
contractility of, clxxiv
distribution of, clxxii
muscular fibres in, clxxiv
openings of lymphatics into, cxc
peculiarities of, clxxiv
plexuses of. *See* PLEXUSES
pulsation in, clxxiv
satellite, clxxiii
structure of, clxxiii
valves of, clxxiv
vessels and nerves of, clxxiv
vital properties of, clxxiv
VEINS, Descriptive Anatomy of, 452
acromial thoracic, 469
alar, 469
angular, 456
auricular anterior, 457
posterior, 457
axillary, 468
azygos, left, or small, 471
right, 469
basilic, 466
brachial, 467
brachio-cephalic, 453
bronchial, 471, 903
buccal, 456
capsular, 474
cardiac, 482
anterior, 483
great, 482
posterior, 483
small, 483
cava, lower, 473
upper, 453
of cerebellum, 460
cerebral, 460
cephalic, 466
of choroid coat, eye, 722
plexus, of brain, 548
circumflex iliac, 477
superficial, 475
of shoulder, 469
coronary, of heart, 321, 482
stomach, 480
of corpora cavernosa, 958
corpus striatum, 460
cranium, 460
dental, inferior, 457
superior, 457
diaphragmatic, 454

VEINS—*continued.*
of diploe, 465
dorsal, spinal, 471
of penis, 479
duodenal, 481
emulgent, 474
epigastric, 477
superficial, 475
of face, 455
facial, 455
communicating, 457
transverse, 457
femoral, 476
frontal, 455
of diploe, 465
of Galen, 460
gastric, 481
gastro-epiploic, 481
of head, 455
heart, 482
hepatic, 474, 867, 871
iliac, external, 477
internal, 477
common, 479
infraorbital, 456
innominate, 453
intercostal, anterior, 454
superior, 455
interlobular of liver, 873
intracranial, 460
intralobular of liver, 870
jugular, anterior, 459
external, 459, 469
internal, 459, 469
posterior, 459
labial, 456
laryngeal, 460
lingual, 459
of liver, 867, 871
of lower limb, 475
lumbar, 473
ascending, 473
mammary, internal, 453
masseteric, 456
maxillary, internal, 457
median basilic, 467
cephalic, 467
cutaneous, 467
mediastinal, 454
meningeal, 457
mental, 456
mesenteric, inferior, 482
superior, 481
nasal, 456
of neck, 455
occipital, 460
of diploe, 465
ophthalmic, 464
ovarian, 474
palatine, 456, 457
palpebral, inferior, 456
superior, 456
pancreatic, 481
parotid, 457
of pelvis, 477

VEINS—*continued.*
peroneal, 476
pharyngeal, 460
phrenic, 474
popliteal, 476
portal, clxvi, 479, 867, 873
sinus of, 480
pudic external, 75
pulmonary, 332, 903
radial cutaneous, 466
deep, 467
ranine, 456
renal, 474
of retina, 729
sacral, middle, 473
saphenous, long, or internal, 475
short, or external, 476
scapular, posterior, 459
spermatic, 473
spinal, 471
anterior longitudinal, 472
posterior longitudinal, 472
of spinal cord, 472
splenic, 480
subclavian, 469
sublobular of liver, 870
submaxillary, 456
submental, 456
subscapular, 469
supraorbital, 456
suprarenal, 474
suprascapular, 459
temporal, 457
deep, 457
middle, 457
superficial, 457
of diploe, 465
temporo-maxillary, 455
thymic, 454
thyroid, superior, 460
middle, 460
inferior, 453
tibial, 476
ulnar cutaneous, anterior, 466
posterior, 466
deep, 467
umbilical of fœtus, 328
development of, 483
remains in adult, 865
of upper limb, 465
deep, 467
superficial, 466
vaginal, 479
of liver, 873
of vertebræ (bodies), 472
vertebral, 469
VEINS, plexuses of. *See* PLEXUSES.
Velum pendulum palati, 189, 813
interpositum of brain, 548
Vena cava, fossa of, in liver, 864
lower, 473
opening in diaphragm for, 246
upper, 453
cordis magna, 482

Vena cava—*continued.*
hemiazygos, 471
portæ, clxvi, 479, 867, 873
tributaries of, 480
salvatella, 466
sine pari, 469
Venæ basis vertebrarum, 472
comites vel satellites (companion or satellite veins), clxxiii, 467, 476
cordis minimæ, 309, 482
parvæ, 483
Galeni (veins of Galen), 460, 548
Venous blood, characters of, xlii
Ventricles (*ventriculus*, dim. of *venter*, a belly), cerebral, of Arantius, 517
of corpus callosum, 541
fifth, 545
fourth, 525
choroid plexuses of, 526
floor of, 517, 525
lining membrane of, 526
lateral, 543
choroid plexuses of, 543
cornua of, 543
of septum, or Sylvian, 545
third, 550
choroid plexuses of, 548
commissures of, 550
communication with lateral ventricles, 548
of heart, 302
capacity of, 322
development of, 323
fibres of, 318
interior of, 305
left, 312
position of, in chest, 315
right, 310
of larynx, 910, 912
Ventro-inguinal (*venter*, the belly; *inguen*, the groin) hernia, 1027
Vermicular motion (*vermiculus*, dim. of *vermis*, a worm), 841
Vermiform process, 522
Vertebra dentata, 9
prominens, 8
VERTEBRÆ, 3
cervical, 7
first and second, 8
coccygeal, 12
cranial, 71
dorsal, 5
fixed, 10
general characters of, 4
homologies of, 21
lumbar, 6
movable, 4
groups of, 5
number of, 4
ossification of, 15, 18, 20
primordial, 16
sacral, 10
serial relations of, 21
typical, 22
Vertebral aponeurosis, 240
artery, 367
column, 3
curves of, 13
form of, 14
ligaments of, 121, 147
ossification of, 15, 18, 20
veins of, 471
segments, 1
Verumontanum (*veru*, ridge), 961
Vesica prostatica, 961
urinaria (urinary bladder). *See* BLADDER
Vesicle, primary auditory, 768
germinal, xv, 990
optic, primary, 737
secondary, 738
Vesicles, air, 899
of glands, cclxxxvi
of De Graaf, 989
changes in, 990
nerve, cxxxix. *See* NERVE-CELLS
seminal, 973
structure of, 974
vessels and nerves of, 975
of thyroid body, 921
Vesico-uterine folds, 986
Vesicular tracts of spinal cord, 510
Vessels. *See* ARTERIES, CAPILLARIES, and VEINS
Vestibule, aqueduct of, 38, 754
of ear, 753
membranous, 757
saccule of, 757
scala of, 757
sinus of, 757
vessels of, 767
of vulva, 978
bulbs of, 979
Vestigial fold of pericardium, 300
Vestigium foraminis ovalis, 309
Vidian canal, 42, 57, 59
nerve, 604
Vieussens, isthmus of, 309
valve of, 554
Villi (*villus*, shaggy hair) cxcix
of small intestine, 842
stomach, 835
Vincula accessoria tendinum, 218
vasculosa, 218
Vis nervosa, viii, clxiii
Viscera of abdomen, 824
dissection of, 1069
position of, in regions, 826
of pelvis, dissection of, 1077
Visceral arches in embryo, 641
cavity, 3
plates, 859
Vital contractility, viii
properties of textures, vii. *See* each tissue
Vitality, vii
Vitelline, (*vitellus*, yelk) duct and sac, 859
Vitreous (*vitrum*, glass) body, 731
table of skull, 60

Vocal cords, 910, 912
Voice, organs of, 905
Volar (*vola*, the palm of the hand) artery, superficial, 397
Voluntary muscles, cxv
Vomer (a ploughshare), 48
ossification of, 70, 71
VULVA, 977
development of, 1001
erectile tissue of, 979
glands of, 978
mucous membrane of, 978
nerves of, 980
vessels of, 979

WHARTON'S duct, 817
jelly, lxxii, lxxviii
Willis, classification of cranial nerves, 582
circle of, 363
Wilson's muscle, 265
Wings, great, of sphenoid bone, 40
small, or of Ingrassias, 40
Winslow, foramen of, 827
Wirsung's canal, 882
Wisdom tooth, 783
Wolffian bodies, 992
Womb, 982. *See* UTERUS
Wormian bones, 55
Wrisberg, cartilages of, 908
ganglion of, 698
nerve of, 646
Wrist-joint, bones of, 83
ossification of, 90, 93
fascia of, 231
ligaments of, 142, 147, 231
movements of, 228

XIPHOID (ξιφος, a sword; εἶδος, shape) process, 23

YELK, segmentation of, xv
Yellow cartilage, lxxxv
fibres of areolar tissue, lxxi
ligaments, 123
spot in retina, 726, 729
tissue, lxxvi

ZONA denticulata, 764
glomerulosa, 939
pectinata, 763
pellucida, 990
reticularis, 939
Zones, abdominal, 823
Zonula Zinnii vel ciliaris, 736
Zygapophyses (ζυγ, root of ζευγνυμι, I yoke, or join together; *apophysis*), 22
Zygoma (a cross-bar, or bolt, from root above given), 36
Zygomatic arch, 36, 57
fossa, 57
Zygomatici muscles, 176

THE END.

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NOTE TO PAGE 180.

At the page indicated, the action of the straight muscles of the eyeball has been shortly described, but no notice is taken of that of the oblique muscles. The omission was deemed advisable, from the difficulty of giving within a short space an intelligible account of a matter still involved in uncertainty; but the attention of the Editors having been drawn to it as a defect which it was desirable to remedy, they have endeavoured to do so in the present note.

The motions of the eye-ball take place round three axes, viz., a transverse, a vertical, and an antero-posterior. Those round the first two axes are effected more immediately by the straight muscles, which have also the power by the successive or concurrent contraction of different ones among them to direct the pupil to all the points of space within the cone by which the movements of direction are limited. The movements of rotation on an antero-posterior axis are no doubt effected chiefly by the oblique muscles; but it is still doubtful to what extent and in what circumstances these movements occur.

By the experiment of Donders, viz., that of turning the head downwards to the side after an ocular spectrum of a bright vertical line has been fixed in the eyes, and which it is easy to repeat with the same result, it is ascertained that the eyes turn accurately with the head, and are not balanced in the vertical position by the rotatory action of the oblique muscles, as was supposed by Hueck and others. The rotation of the eyes by the oblique muscles must therefore have some other object.

When the optic axis is directed straight forwards, the simple action of the superior oblique muscle (as ascertained by experiment on the dead subject) is to direct the pupil with some degree of rotation downwards and outwards; that of the inferior oblique to produce a similar movement in an upward and outward direction; and no doubt both muscles acting in concert on one eye, while the optic axis is still straight forward or is somewhat everted, may produce a horizontal outward movement of the pupil. But if on the other hand the eye is turned forcibly inwards, it is conceivable that, as then the points of insertion of the oblique muscles will be brought further forward, these muscles may along with other movements give an inward direction to the pupil.

The most important actions of the oblique muscles probably take place in combination with one or more of the straight muscles. Careful observations appear to have proved that the recti muscles are incapable of altering materially the form of the eyeball, or of diminishing its distance from the back of the orbit; and it is equally certain that the oblique muscles have little or no effect as antagonists in drawing forward the eyeball. It would appear, however, that while the external and internal recti muscles act exactly in the horizontal plane between them, so as not to produce any upward or downward direction along with their horizontal movements, the superior and inferior recti, from the obliquity of the line in which they proceed forwards towards their insertion, have both a tendency to direct the eye somewhat inwards. It seems very probable, according to the views stated in the papers referred to below, that the inward direction produced by the superior or inferior rectus may be corrected by the combination of the action of different oblique muscles with that of one or other of the recti muscles; *i. e.*, the inferior oblique with the superior rectus, and the superior oblique with the inferior rectus. In a similar manner the oblique muscles may also counterbalance an increased inward direction given by the internal rectus, and increase an outward direction given by the external rectus.

On the whole, it seems probable that the oblique muscles have the effect of maintaining accurately the parallelism of the two eyes by balancing the action of the several sets of straight muscles.

See for an account of this subject and its application to the study of different forms of paralysis of the muscles of the eye, a paper by Dr. John S. Wells in the Ophthalmic Hospital Reports, &c., vol. ii. 1859-60, p. 44; and a paper by Von Graefe on the Physiology and Pathology of the Oblique Muscles of the Eye in the Archiv für Ophthalmologie, vol. i. part i. p. 1.

CORRIGENDA AND ADDENDA.

Page 13, line 17th from bottom, *transpose* the words "posterior" and "anterior."
— 17, line 4th from bottom of the description of Fig. 15, *after* "three places" *insert* "to," and in the succeeding line, *before* "three" *insert* "to."
— 18, in title of Fig. 16, *omit* "figs. 80 and 81."
— 20, in description of Fig. 19, *add under C*, "one-third the natural size."
— 22, line 14th, *after* "corresponds to" *insert* "the."
— 23, *before* "THE THORAX," *insert* "II."
— — in the description of A, Fig. 21, *after* "interclavicular notch" *insert* "12."
— 29, *before* "THE BONES OF THE SKULL" *insert* "III."
— 35, line 2nd, *after* "foramina" *insert* "; 16, transverse suture."
— — line 27th, *after* "malar" *insert* ", and by the glenoid cavity with the inferior maxillary bone."
— 47, line 15th from bottom, for "fossa on its sides;" *read* "fossa; on its sides."
— 52, line 12th, *for* "from which the external pterygoid muscle arises," *read* "into which the external pterygoid muscle is inserted."
— 56, line 4th from bottom, *after* "the figure is" *insert* "the outer or deflected plate of the inferior turbinated bone, and over that."
— 73, line 13th from bottom, *for* "Crana" *read* "Crania."
— 79, line 22nd, *for* "musculo-spinal" *read* "musculo-spiral."
— 80, line 13th from bottom, *after* "upper part" *insert* "superiorly by an oblique line or ridge, and lower down."
— 94, in the description of Fig. 85, *before* "13, tuberosity, &c." *insert* "12, spine of the ischium."
— 101, at the middle, *for* "*trochanteric*" *read* "*intertrochanteric*."
— 106, lines 12th and 13th from bottom, *for* "to which the interosseous ligament is attached" *read* ", the interosseous ridge,".
— 107, line 16th, *for* "largest" *read* "larger."
— 108, line 8th, *for* "largest" *read* "larger."
— — under the Cuboid Bone, line 11th, *for* "surface" *read* "aspect."
— 115, line 3rd from bottom, *after* "ulna" *insert* "of the opposite side of the body;" and in the bottom line, *after* "radius" *insert* "of the same side of the body."
— 143, in the woodcut, Fig. 132, B, *omit* "12" close to the fifth metacarpal bone.
— 146, line 14th from bottom, *for* "metacarpal, interosseous, and palmar," *read* "interosseous and palmar metacarpal;" and in the 6th, 7th, and 8th lines from bottom, *transpose* the words "distal" and "palmar," and *delete* the words "and their interosseous ligaments are put upon the stretch."
— 147, line 17th from bottom, *omit* "symphysis or."
— 154, line 6th, *after* "membrane" *insert* "in the middle it is attached to the internal semilunar cartilage; and."
— 158, line 10th from bottom of the small print, *after* "the external" *insert* "and internal."
— 184 and 192, in the description of Figs. 160 and 166, *for* "*e*, front of the thyroid cartilage," *read* "*e*, placed on the front of the thyroid cartilage, points to the thyro-hyoid muscle."
— 194, in description of Fig. 167, line 4th, *after* "muscle" *insert* "; 15'."
— 196, line 5th, *for* "sixth vertebræ" *read* "sixth cervical vertebræ."

Page 205, in the woodcut, Fig. 173, the lower part of the coraco-brachialis muscle is misplaced behind the tendons of the latissimus and teres major: it ought to have been represented as cut across like the biceps. In Fig. 200, p. 254, the same error occurs.
— — line 2nd from top, *for* "*b*" *read* "6."
— — line 2nd from bottom, *for* "biceps" *read* "triceps."
— 221, in description of Fig. 182, line 7th, *after* "ulnaris;" *insert* "15′, its insertion into the fifth metacarpal bone."
— 222, in description of Fig. 183, line 8th, *after* "tendon of," *instead of* "the flexor; 3, carpi ulnaris;" *read* "3, the flexor carpi ulnaris."
— 226, in the middle, *after* "masses of fibres" *insert* "proceed."
— 230, line 29th, *instead of* "aponeurosis" *read* "aponeurotic."
— 233, after the last line of the paragraph describing the serratus posticus inferior, *insert* "(*See* Fig. 71, p. 202)."
— 237, in the last line but one of the description of Fig. 191, *after* "posticus" *insert* "minor."
— 242, in the woodcut, Fig. 164, the ninth rib is erroneously marked "XI."
— 247, line 25th, *for* "Hutchison" *read* "Hutchinson."
— 249, in bottom line, *for* "Ponpart's" *read* "Poupart's."
— — line 5th from bottom, *for* "aba" *read* "alba."
— 261, *insert* a "comma" at the end of the first line of the paragraph in small print.
— 320, bottom line, *prefix* "*."
— 333, in description of Fig. 249, line 5th from bottom, *for* "sphenic" *read* "splenic."
— 447, near middle, in 1st line after "BRANCHES," *for* "*metacarpal*" *read* "*metatarsal.*"
— 577, line 2nd from bottom of foot-note, *for* "Twischenhirn," *read* "Zwischenhirn."
— 592, last line but one of description of Fig. 401, *for* "409" *read* "408."
— 765, in the diagrammatic view of a section of the lamina spiralis, &c., Fig. 522, the cellular structure filling the sulcus spiralis is represented too strongly and regularly.
— 929, line 17th from bottom, *for* "Fig. 659" *read* "Fig. 661."
— 931, line 17th from bottom, *for* "The glomerulus" *read* "The capsule."

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